HURRICANE PROTECTION PROJECT

FOX POINT

HURRICANE BARRIER

PROVIDENCE RIVER, PROVIDENCE, RHODE ISLAND

DESIGN MEMORANDUM NO. 11

COOLING WATER CANAL

U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

MARCH 1960

ENGCW-E (4 Mar 60) 1st Ind
SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 11 - Cooling Water Canal

Office, Chief of Engineers, Washington 25, D. C., 23 March 1960

TO: Division Engineer, U. S. Army Engineer Division, New England
WALTHAM, MASSACHUSETTS

Design Memorandum No. 11, Cooling Water Canal, is approved subject to the following comments:

a. In view of the silts that exist in the foundation and the possible danger of liquefaction, it is suggested that all piles be wide flange steel piles rather than pipe piles and timber piles.

b. The depth of granular fill in the canal appears excessive in some areas, for example as shown on Section 4 Station 2+02, Plate 11-12. If it is necessary to remove existing material to the depth shown to prevent intermixing of the organic deposit and the granular material the amount of refill could be limited to a depth of two or three feet unless more is needed to insure bank stability. The additional depth of water should not be hydraulically objectionable. The canal bottom profile should be examined to determine the possibility of the indicated saving in the cost of placing fill.

c. Omit the splines from wall panels and flap gates.

d. The description of the flap gate hardware in the design memorandum differs from that shown on Plate 11-10. These differences should be reconciled and the use of non-corrosive metal for the hinge assembly is recommended.

e. Section X, Corrosion Protection, does not contain sufficient information to permit an adequate review. A detailed design memorandum covering the protection of the steel in the subject structure against corrosion should be submitted. The design memorandum should contain cost comparisons of the various schemes of protection.

FOR THE CHIEF OF ENGINEERS:

Incl w/d

F. B. SLICHTER
Chief, Engineering Division
Civil Works

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54. MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO. NEDGW

4 March 1960

SUBJECT: Fox Point Hurricane Barrier, Providence, Rhode Island, Design Memorandum No. 11 - Cooling Water Canal

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTN: ENGCW-E

In accordance with EM 1110-2-1150 there is submitted herewith for review and approval 10 copies of Design Memorandum No. 11, Cooling Water Canal.

FOR THE DIVISION ENGINEER:

John Wm Leslie

JOHN WM. LESLIE
Chief, Engineering Division

1 Incl
Des Memo No. 11,
Cooling Water Canal -
Fox Point

FOX POINT HURRICANE BARRIER
PROVIDENCE
RHODE ISLAND

DESIGN MEMO NO. 11

COOLING WATER CANAL

INDEX TO DESIGN MEMORANDA

No.	Title	Submission Date	Approved
1	Geology	9 October 1959	6 Nov 1959
2	Hydrology		
	Preliminary	3 June 1959	8 June 1959
	Final	17 November 1959	21 Dec 1959
3	Deleted		
4	Hurricane Tidal Hydraulics	29 January 1960	
5	General Design Memo	22 December 1959	29 Jan 1960
6	Embankment & Foundations		
7	Structural Section I		
8	Structural Section II		
9	River Gates	29 January 1960	
10	Pumping Station	22 January 1960	
10A	Foundation Pile Design		
11	Cooling Water Canal		
12	Sewer & Utility Modifications	29 January 1960	
13	Cooling Water and Erosion Considerations	8 January 1960	8 Feb 1960
14	Concrete Materials	3 November 1959	27 Nov 1959

FOX POINT HURRICANE BARRIER
PROVIDENCE, RHODE ISLAND
DESIGN MEMORANDUM NO. 11
COOLING WATER CANAL

CONTENTS

Paragraph	Subject	Page

LIST OF PLATES

APPENDIX - TYPICAL DESIGN COMPUTATIONS

Index to Sheets

FOX POINT HURRICANE BARRIER
PROVIDENCE RIVER
RHODE ISLAND

DESIGN MEMORANDUM NO. 11

COOLING WATER CANAL

A. GENERAL

1. Purpose. - The purpose of this memorandum is to describe the design criteria and operational and site considerations that established the basis of design for the Cooling Water Canal which is an integral feature of the Fox Point Hurricane Barrier on the Providence River in Providence, Rhode Island. This complete memorandum includes sections on geology, soils, canal hydraulics and structural design. The cooling water intake canal with its associated structures will service two major electrical generating stations which are situated immediately upstream of the Fox Point Hurricane Barrier.

B. CANAL LOCATION AND DESCRIPTION

2. Location. - The cooling water canal will be located within the Providence River along the westerly shore commencing from the main barrier pumping station on the south and preceding in a northerly direction under the existing Point Street Bridge and continuing to a point above the South Street Station northerly intake whence it returns into the west shore bulkhead. The location of the cooling water canal with respect to the other river components of the barrier is indicated on Plate No. 11-1.

3. Description. - The cooling water intake canal will be formed within the Providence River by the installation of a canal wall consisting of vertical and battered steel H-piling with creosoted timber panel inserts. The harbor cooling water intake gates will be located within the westerly end of the barrier pumping station. Two sets of four flap gates each will be located in the canal wall south of the Point Street Bridge. Two discharge flume extensions will be provided for the Manchester Street generating station and one discharge flume extension will be provided for the South Street generating station to pass hot discharge water through the cooling water canal into the Providence River upstream of the barrier. The alignment of the cooling water canal and location of appurtenances are shown on Plate Nos. 11-2 and 11-3.

C. FUNCTION OF THE COOLING WATER CANAL

4. General. - The Narragansett Electric Company operates two power generating stations which are located along the west bank of the Providence River. Both the Manchester Street and South Street generating stations are located upstream (north) of the proposed location of the Fox Point Hurricane Barrier. Both of these power stations are of the steam generating type that rely on the drawing of condenser cooling water from the Providence River. Tests were made on the existing Narragansett Bay model located at the Waterways Experiment Station at Vicksburg, Mississippi(Interim Report 3, September 1959) and the results indicate that the barrier, when completed, would effect a reduced vertical circulation which would result in an increase in the average water temperature in the area upstream of the hurricane barrier of 3.0 to 3.5 degrees. Furthermore, the tests of the cooling water canal scheme designated as Plan 3 (Interim Report 4 September 1959) indicate that all detrimental effects of the Fox Point Hurricane Barrier on the cooling water temperature would be eliminated by this plan. The results of the model test indicate that the average temperature at the Manchester Street Station would be significantly lower than that for existing conditions and the average temperature at the South Street Station intakes would be no higher than those based on existing conditions. The design of the cooling water canal as proposed is substantially the Plan 3 scheme except for the location of the gated opening in the barrier which is planned west of the model location. The cooling water canal as shown on Plate 11-1, will provide the necessary cooling water from downstream of the barrier at a maximum rate of 1,000 cfs.

D. GEOLOGY

5. General. - The cooling water canal lies within the northern end of the Providence River estuary and the general geology of this area is described fully in Design Memorandum No. 1, "Site Geology". It is significant to note, however, that both the bedrock and glacial till stratum rise in elevation proceeding in an upstream direction from the barrier location. The thickness of the glacial till deposit also increases proceeding in a northerly direction. These factors influence the design of the cooling water canal wall which is generally oriented in a north-south direction. See Plate No. 11-1.

E. SUBSURFACE INVESTIGATIONS

6. General. - A comprehensive program of field subsurface investigations was undertaken to obtain the data required for the foundation design of the cooling water canal wall and discharge flume extensions. These investigations included soundings of the existing river bottom, borings from which disturbed (drive) samples and undisturbed (tube) samples were obtained, and bar probings to obtain

penetration data at intervals between the borings to permit better delineation of stratification between borings. Bedrock investigations were not made along the site of the cooling canal wall; however, a discussion of bedrock conditions may be found in Design Memorandum No. 1, "Site Geology".

a. An analysis and interpretation of the field data from the borings and soundings was conducted and in conjunction with the laboratory test data, resulted in the establishment of the soil properties of the various soil strata encountered. These properties were necessary for the design of the cooling water canal wall and were important in establishing the recommended construction procedures.

7. Subsurface Explorations. - Subsurface explorations were conducted to obtain soil samples and data concerning the subsurface soil conditions pertinent to the design and construction of the cooling canal wall and its appurtenances. These explorations constituted a part of the overall program of field investigations for the Fox Point Hurricane Barrier Project. Initially four borings were made along the canal wall location from which disturbed (drive) samples were obtained. These borings were taken into the glacial till. Subsequently, three additional borings were drilled along the canal wall location, from which undisturbed thin-wall tube samples were taken of the upper strata of organic and inorganic silt. These borings were shallower in depth than those previously taken. In addition to the borings described above, three borings were taken directly in front of both the Manchester Street Station intake and the South Street Station south intake. Undisturbed thin-wall tube samples were recovered in order to determine the properties of the upper stratum of the loose organic silts immediately in front of the intake structures. Two lines of bar probings were also driven in the Providence River, with probings spaced on approximately 100-foot centers along these lines. The inner line of probings extended along the existing west bank bulkhead for the length of the proposed cooling water canal, as close as practicable to the bulkhead wall structure. The outer line of probings was taken along a line approximately 75 feet from and parallel to the west shore bulkhead along the length of the cooling water canal. Isolated probings were also taken on the south side of each of the piers of the existing Point Street Bridge. Soundings were taken to develop contours of the top of the soft river bottom sediments. Plate Nos. 11-2 and 11-3 show the locations of those foundation test borings and foundation probes that apply to the cooling water canal. The log profiles of the borings and probes along the cooling canal are shown on Plate No. 11-4.

8. Purpose of Explorations. - The exploration program was developed to investigate the subsurface soil strata in the area of the cooling water canal to:

a. Furnish sufficient data for the preparation of the generalized soil profiles showing the type, thickness, extent and distribution of the subsurface soils as required for design and construction purposes.

b. Obtain undisturbed tube samples and disturbed drive samples for classification, examination and laboratory testing as required to determine the physical characteristics for design and construction purposes.

9. Procedure. - The foundation test borings were made utilizing 3-1/2-inch and 4-1/2-inch pipe casing. Drive samples were taken employing 2-inch and 2-1/2-inch inside diameter solid sampling spoons 5 feet long that were driven by a 300-pound or 350-pound hammer falling approximately 18 inches. In general, the smaller sampling spoon was used when relatively dense material was encountered. The number of hammer blows required to advance the sampling spoon each foot were recorded on the logs. After each drive, the sampling spoon was withdrawn from the bore hole and the soil sample removed. Each sample was examined by the field inspector, who assigned visual field classifications in accordance with the Unified Soil Classification System. Representative specimens were placed in jars which were then sealed with wax to preserve natural moisture contents which were determined in the laboratory. Undisturbed tube samples were obtained by the use of a 3-inch inside diameter thin-wall tube sampler. The tube was positioned at the sampling depth after cleanout and then hydraulically pressed into the underlying soil to secure the undisturbed sample. The tube and sample were then retrieved from the bore hole and the tube was immediately sealed with wax to preserve the soil specimen in as close to natural conditions as possible for shipment and subsequent laboratory testing.

10. Laboratory Testing. - The drive samples and undisturbed tube samples were visually classified at the New England Division soils laboratory in accordance with the Unified Soil Classification System, and the field classifications assigned initially by the field inspector were modified as necessary. Grain size analyses and Atterberg Limits were determined for representative samples to augment the visual field classifications. Specific gravity and natural water content determinations were made of samples selected from the principal soil types. Unconfined compression tests and triaxial compression tests were performed on the cohesive and plastic soil samples. The necessary identification, characteristics, moisture contents, in situ densities and void ratios and specific gravities were determined for the cohesive and plastic soils used in the shear tests.

11. <u>Characteristics of Soil Strata</u>. - There are three major soil deposits to be considered within the river in the design and construction of the cooling water canal. West of the existing bulkhead an additional layer is involved. These are as follows:

a. A surface layer of very soft organic silt (OH) of recent origin.

b. A deposit of alluvial materials consisting of silty sands (SM and SP-SM) and sandy gravels (GP-GM) which generally overlie and occasionally interbed with a deposit of stratified or laminated sandy inorganic silt (ML).

c. A heterogeneous deposit of compact silt, sand and gravel containing cobbles and occasional boulders typical of the local glacial till (SM-GP-GM) deposits which overlie the bedrock.

d. Inboard of the west shore bulkhead, miscellaneous fill has been deposited over the original upper layer of organic silt.

12. <u>River Bottom Sediments</u>. - The river bottom sediments consist generally of very soft to soft organic silts of medium to high plasticity (OL and OH) containing inclusions of thin discontinuous lenses of sand and occasional gravel. In addition, pieces of coal and wood fragments were found within the organic silt deposit, and a strong odor of oil was noted from some samples. A considerable penetration of this stratum by the sampling device was experienced as a result of just the weight of drill rods or the rods with the hammer resting on them. The resistance to penetration increased with depth and hammer blow counts upon the sampling devices are recorded for the lower levels of the deposit. The thickness of the organic silts is somewhat erratic along the length of the cooling canal wall and also varies transversely within the canal. Because of the frequent granular inclusions, the exact vertical delineation of this deposit by penetration resistance alone is not considered reliable and the use of continuous sampling procedures at the boring locations provided the most accurate data.

13. <u>Uppermost Layer of Organic Silts</u>. - The extreme softness and sensitivity of the uppermost layer of the organic silt deposit made it virtually impossible in some instances to obtain any thinwall tube samples. Furthermore, some of the undisturbed samples that were recovered proved upon extrusion to be of such a nature that it was not possible to perform tests on them to establish shear strengths. Laboratory analysis indicates that the natural water contents of the organic silt ranges between 50 percent and 300 percent. Liquid limits generally varied from 65 to 120, and plasticity indices ranged from 30 to 60. Three samples tested indicated liquid

limits of about 160 and plasticity indices about 110. Determinations of specific gravity of the organic silts varied between 1.99 and 2.67. In situ dry densities reported by the laboratory varied from 41 to 79 pounds per cubic foot. Unconfined compression strengths were reported to range between 0.06 and 0.47 ton per square foot. The organic content of the organic silt deposit was found to vary from 5 percent to 16 percent.

14. Underlying Silt Layers. - The alluvial deposits consist primarily of loose to medium compact, slightly plastic sandy inorganic silts (ML). In some samples, layers of silt alternated with layers of sand and sandy silts, and were reported as being laminated. The maximum thickness of sandy silts encountered in the borings was in the order of 35 feet. However, at several boring locations, layers of silty sands (SM and SP-SM) and sandy gravels (GP-GM) were found within the sandy silts, and at one boring the sandy silts were not reported within the alluvial deposits by the driller. The thickness of the alluvial deposits vary from 15 feet to 35 feet. Laboratory analysis of the sandy inorganic silts indicates a liquid limit of 27 and a plasticity index of 7. The dry density of the sandy silts was determined to be approximately 97 pounds per cubic foot. Natural water contents were observed to vary from 21 to 32 percent and averaged about 27 percent. One series of constant stress consolidated-drained triaxial compression tests were performed on the undisturbed samples of the sandy silts. The resulting Mohr strength envelope indicated a cohesion of 0.23 ton per square foot and an angle of internal friction of 39.5 degrees for this soil. The latter value is considered to be too high for a representative evaluation of the entire deposit. Shear tests were not performed on the cohesionless sands and gravels found in the general alluvial deposit. Natural water contents for these coarser-grained materials were reported to be approximately 10 percent.

15. Glacial Till. - The glacial till was encountered below the alluvial deposits. This material was described by the driller as consisting of a compact to very compact gravelly silty sand (SM) and a silty sand gravel (GM). Cobbles and boulders were also reported within the till deposit. The glacial till was encountered along the line of canal wall borings at elevations ranging between minus 47.0 m.s.l. and minus 71.0 m.s.l. No laboratory analysis was made of the drive samples recovered from this material. The results of the laboratory analysis performed on the soil samples are shown on Plate Nos. 11-32, 11-33 and 11-34.

F. DESIGN OF COOLING WATER CANAL

16. General. - The design of the cooling water canal is based on numerous considerations. The more important of these considerations are the operational requirements of the Narragansett Electric Company, the nature and condition of the west shore bulkhead, the protection of the cooling condensers against the corrosive river sediments, and the effects of and protection against the scour of the canal bottom, and the prevention of boiling of bottom sediments resulting from differential heads on the canal wall.

17. Head Losses. - The design of the cooling water canal further considered keeping the head losses at a practical minimum. The Narragansett Electric Company has expressed the attitude that the design of the canal should not create substantial increases in pumping heads for their cooling condenser system. For a future flow of 1,000 cfs assuming all future flow increases occurring at the South Street Station, the head loss from the harbor at minus 6.0 m.s.l. to the most distant intake at South Street Station would be about 0.6 foot. Since a low tide of minus 5.5 m.s.l. occurs only once in about 10 years, the lowering of the water surface is not critical and is not expected to induce cavitation or air entrainment in the cooling water pumps. Although pumping heads would be somewhat higher than exist presently, a certain amount of head loss is unavoidable. However, the losses resulting from the proposed canal sections are considered reasonable.

18. Treatment of Canal Bottom. -

a. Existing Conditions. - The existing section of the projected cooling water canal is very irregular. Portions of the bottom must be excavated in order to provide the necessary cross-section for hydraulic flow requirements. The existing bottom consists of an organic silt, the top layer of which is very loose. The existing river wall forming the west bank of the canal is generally of old stone masonry construction. In certain locations where operations of the Narragansett Electric Company have necessitated, this wall has been rebuilt. Construction details and foundation elevations for the original stone masonry wall are not available. However, similar walls demolished for nearby expressway construction were observed to have been founded on granite slabs, supported on single wood piling centered under the slab. At other locations the wall is believed to be founded on timber mats.

b. Recommended Treatment. - Consideration was given to establishing a flow velocity which would not scour the organic silt either in its flocculent form or when excavated to firmer depths. Dr. Ippen of Massachusetts Institute of Technology, who is an expert in this field, expressed the opinion that for the project conditions it would not be possible to select a critical scour velocity, either from study of many articles that have been written on the subject or the testing of undisturbed samples in a model flume or by field observations of currents and existing river bottom. It was his recommendation that the loose top material be removed and the protective sand layer be placed on top.

(1) At a recent session of the Tidal Hydraulics Board it was estimated that a safe eroding velocity for the firmer underlying silt would be in the order of 0.55 foot per second. The attainment of such a velocity would necessitate widening the canal, thereby lengthening the discharge flume extensions and utility extensions and by such, adding considerably to the construction costs. Also, there exist several areas of high localized velocities that could not be eliminated due to space and area limitations. In view of these considerations, the attainment of such a low critical velocity is considered impractical if not actually impossible.

(2) Accordingly, it was decided to line the entire cooling water canal with a sand blanket in addition to the more extensive treatment required at those areas of high velocities.

19. Excavation of Canal Bottom. - For hydraulic considerations, hereinafter described, maximum elevations for the canal widths utilized were established to insure velocities sufficiently low to preclude scour of a sand and gravel blanket. Accordingly, the excavation of the existing river bottom material was influenced by these elevations. The stability of the west shore bulkhead depends to some degree upon the presence of the existing sediments in front of the bulkhead. Excessive excavation in front of the bulkhead must be avoided if stability is to be assured. To determine the minimum required dredge line, the following criteria was utilized:

a. The depth of the very soft organic silts immediately in front of the bulkhead established the minimum required depth of excavation along the bulkhead. This delineation between the very soft sediments and the firmer (more consolidated) or more granular organic silt was based on the depth to which this deposit was penetrated by the sampling device or probe without any driving effort. The Contractor will, however, be required to verify in the field the bottom elevation of all existing west shore bulkhead construction prior to the dredging operation.

b. A line with a slope of 2 horizontal to one vertical was projected from this point along the bulkhead into the canal until it intersected with the horizontal surface of the proposed canal bottom. Total excavation of the organic silt within the canal is unwarranted and unnecessary. The minimum depth of excavation is governed by hydraulic considerations and based on a minimum thickness of the select granular refill of 2 feet. The maximum depth of the required dredging is based on the dead weight penetration of the sampler or probe rod. This depth is considered as representing those sediments that are too soft to support the granular refill. Upon exposure of a surface capable of supporting the refill, granular material will be placed to elevations indicated for the finish sections for the hydraulic profile and then continued on the slope to the existing bulkhead.

20. Lining of Canal Bottom. -

a. Material. - The bottom of the cooling water canal, with the possible exception of areas where the existing excavated bottom is found to be of suitable sand, will be lined with coarse sand. Coarse sand is generally considered safe against scour for velocities of about 2 feet per second. Since much of the sand bottom is on a 2 to one slope, it will scour more readily than a flat bottom. The sand lining is also required to prevent the boiling up of mud into the canal due to seepage resulting from differential head on the canal wall. Constrictions and bends producing an increase in velocity make a higher factor of safety against scour desirable. Accordingly, coarse gravel which is safe against scour for velocities of about 4 feet per second, will be provided for those regions of expected higher velocities.

b. Placement of Material. - The placement of the granular refill will be accomplished in any one area of the canal immediately after dredging to the required elevations. The method of placement has been discussed with numerous marine contractors and will probably be deposited by the use of clamshell buckets or similar equipment. For sections through the cooling water canal, see Plate Nos. 11-12 through 11-17.

21. Stability of West Shore Bulkhead. -

a. Soil Properties. - An investigation was made with regard to the stability of the west shore bulkhead. The soil properties, upon which the stability analyses were based, are presented in the following table. The values of cohesion and the angle of internal friction for the organic deposits in back of the existing west shore bulkhead were established by investigating the stability of the existing bulkhead based on a factor of safety in the order of unity.

Soil Deposit	Dry Unit Weight Lbs./Cu.Ft.	Buoyed Unit Weight Lbs./Cu.Ft.	Cohesion C Lbs./Sq.Ft.	Angle of Internal Friction ϕ
Organic Silt				
Upper layer (river)	--	20	0	0
Lower layer (river)	--	30	600	0
Back of bulkhead (shore)	--	35	1,000	15°
Sand and gravel blanket	90	55	0	30°
Fill (back of bulkhead)	85	50	0	30°

(1) The soil properties tabulated above for the upper and lower layers of the organic silt deposit in the river were obtained from the interpretation of the results of the laboratory testing program. No value of cohesion was assigned to the very soft upper layer of organic silt inasmuch as observation of the soil recovered and subsequent attempts to test it indicated that its shear strength characteristics were of a very low order. The use of a higher value of cohesion and the assignment of a low value of internal friction angle for the organic silt behind the existing bulkhead was based on the fact that this material was considered to have been consolidated under the weight of the overlying surface layer of miscellaneous fill material and were based on the results of stability checks upon existing sections.

b. Existing Stability. - Stability analyses were made upon several sections of the existing west shore bulkhead, and the factor of safety against a circular sliding failure was computed using the values of cohesion and internal friction tabulated above. The following factors of safety were indicated:

Section	Station	Critical Factor of Safety for Circular Sliding Failure
4	2+02	1.02
11	5+58	1.15
15	7+38	1.08
20	9+76	1.30
25	11+97	1.03

These computations of the stability of the existing bulkhead conditions were based upon a river level of elevation 3.0 m.s.l. and the soil behind the bulkhead being moist between elevation minus 3.0 m.s.l. and elevation plus 3.0 m.s.l. Above the latter level, the soil behind the bulkhead was considered to be damp.

c. Stability after Dredging. - A series of trial arcs was utilized to determine the most critical condition of stability. The results of these trials indicated that the minimum factor of safety would exist when the canal area is dredged to its maximum depth coincident with a low tide at elevation minus 5.0 m.s.l. and with the soil considered to be moist behind the bulkhead to a high tide of elevation 3.0 m.s.l. Further investigations indicated that the critical cylindrical surface occurs within the organic silt deposit with a tangency occurring along the lower boundary of the loose upper portion of the organic silt deposit. This delineation between the soft and firmer organic silt material was based on the boring and probing resistance to penetration data. At some locations, numerous existing timber piles occur at various distances from the bulkhead within the river; however, since no data is available as to the tip elevations of these piles, they were not considered as contributing to the stability of the bulkhead. It is very likely, however, that these piles were driven to derive their support in the denser materials at lower elevations and would provide added resistance against a cylindrical slide failure. The results of the slip circle analyses for typical locations along the bulkhead are shown on Plate No. 11-30 and the factors of safety against a rotative failure during construction range within narrow limits in the order of unity. Upon completion of the refill operation the stability is improved considerably. Since the critical condition of low tide is of periodic short duration and allowing for the presence of the existing timber piles which undoubtedly contribute to the stability, the proposed dredging and refill operations are considered feasible. The Contractor will be required to accomplish this phase of the work in moderate increments, in order not to unduly jeopardize long lengths of the existing bulkhead at any one time.

22. Protection against Intake of Organic Silt. - An important consideration in the design of the cooling water canal is to prevent the organic silt from any river bottom disturbance from entering the condenser cooling water system. The organic silt which presently exists on the bottom of the Providence River and which may be deposited in the future is and will be in the process of anaerobic decomposition producing corrosive hydrogen sulfide gas. If the organic silt is picked up by the cooling water, it may damage the condenser tubes. The construction of the cooling water canal will be completed as the first item in the construction of the Fox Point Hurricane Barrier. During the construction of the cooling water canal, separate sections of the canal will be isolated by sheet pile

diaphragms and dredging will be carried out within these enclosures without terminating the supply of cooling water. In spite of these protective measures, it is expected that there will be minor amounts of organic silt released into the cooling water from the driving of sheet piling and from the dredging operation, particularly in the immediate vicinity of the intake screen houses where prolonged interruption of service is not possible. Also, periodic deposition of organic silt is to be expected in times of high tide and low water use and subsequent scour in times of low tide and high water use. However, such entrainment of organic silt will be minor and much less than exists presently.

23. Design at Submarine Cable Crossing and at Point Street Bridge. -

a. Data on Cables. - The Narragansett Electric Company is very much concerned about possible disturbances to their 115,000-volt submarine cables located just north of Point Street Bridge. They have gone on record in writing stating "It is vital that the cables be not disturbed in any way.". There are eight cables at about elevation minus 9.5 m.s.l. with a rather shallow mud cover in the region between the west abutment and the first bridge pier. In the area lining up with the first and second piers from the west shore, the cables slope down to about elevation minus 33.0 m.s.l. Both the locations and elevations of these cables are known only approximately and it is not known how much slack, if any, presently exists. In the event the cooling water canal was to be located between the west abutment and the second bridge pier from the west abutment, serious disturbances to the cables would occur. Replacing a short section of cables and splicing them at the canal is not possible because of resulting interruption of service and the nature of the cables which are oil-filled. The make-up of these cables is as follows:

0.5 inch hollow core
1,000,000 CM copper
0.48 inch paper
0.149 inch lead
Type JWJ #4 BWG galvanized wire armor
Jute outer wrapping
Approximate outside diameter -
3 to 3-1/4 inches.

b. Alternate Schemes for Protection. - Supporting the existing cables and excavation around them is possible but at considerable risk of disturbance. Replacing the cables all the way across the river is not justified economically since the replacement cost has been estimated at approximately $300,000. An alternative study of replacing these cables by an overhead transmission line proved to be unsatisfactory from an operational and economic standpoint. The most practical solution is to relocate the cooling water canal into the section of the river where the cables are sufficiently deep and would not be disturbed by canal construction.

c. Bridge Piers. - The first two bridge piers adjacent to the west abutment are rather shallow and if either one was located within the cooling water canal, about 15 feet of excavation around the piers would be required. Sheet pile protection all the way around the existing piers would be necessary. The third pier is much deeper and it is possible to excavate to elevation minus 20.0 m.s.l. around it without sheet piles. Because of extremely limited overhead clearance under the bridge, driving of sheet piles for protection of existing piers would be very difficult between the abutment and the third pier. Between the third pier and the swing span pier, piling can be readily driven since the swing span can be opened for driving of sheet or other piles by special arrangement with the City of Providence.

24. Study of Alternate Canal Locations. - Several schemes for location of the cooling water canal in order to avoid damage to the submarine cables were considered. They were:

Scheme A - Canal between first and third piers.
Scheme B - Canal between second and swing span piers.
Scheme C - Canal between third and swing span piers.

One of the important considerations in evaluating the alternate locations is encroachment on existing river flow area by the canal construction. For the design pump flow of 7,000 cfs at elevation minus 3.0 m.s.l. based on a flow with existing river bottom, the average velocities under Point Street Bridge would be approximately as follows: Present conditions, 1.9 feet per second; Scheme A, 1.9 feet per second; Scheme B, 2.1 feet per second; and Scheme C, 2.5 feet per second. For the standard project flood of 24,000 cfs at elevation 0.0 m.s.l. and with the average river bottom scoured 5 feet by flood flow, the average velocities under Point Street Bridge would be approximately as follows: Present conditions, 3.4 feet per second; Scheme A, 3.6 feet per second; Scheme B, 4.0 feet per second; and Scheme C, 4.8 feet per second. Scheme A, with the canal between the first and third piers, requires surrounding the second pier with sheet piles, comes closest to the submarine cables and results in a rather irregular channel. Even though Scheme A requires somewhat shorter length of canal walls and creates somewhat less obstruction to the river flow than Scheme B, it was not recommended. Scheme C, with the canal between third and swing span piers, reduces the existing cross-sectional area of the river appreciably. The head losses through the constriction, amounting to less than 0.1 foot during pumping operations and about 0.2 foot for standard project flood, are relatively minor. However, high velocities would scour the river bottom through the constriction and may endanger the existing bridge piers, particularly the three on the east side of the river and, therefore, should be avoided. The velocities under Point Street Bridge would be increased by about 40 percent over the present conditions for Scheme C. Even though Scheme C requires no special protection to existing piers other than the canal walls and results in the most regular channel for cooling water canal, it restricts the river channel appreciably and was, therefore, not recommended.

25. Selected Canal Location. - Scheme B, with the canal located between the second and swing span piers, presents the best solution as it affords the least river channel restriction possible without the necessity of overexcavating at the piers. Surrounding the third pier with sheet piles would not be required. For protection against scour, riprap would be placed around the pier, sloping down from the elevation of the existing riprap adjacent to the pier to elevation minus 20 m.s.l. at the bottom of the canal. Scheme B minimizes any disturbance of the submarine cables, does not obstruct the river area appreciably, provides a reasonably smooth canal, does not require extensive protection of existing bridge piers and does not require excessive length of canal walls.

26. Deflector Wall. - Since no dredging is contemplated in the vicinity of the submarine cables where they occur at higher elevations, especially the area immediately adjacent to the Point Street Bridge, a flow deflector wall is required along the south side of Point Street Bridge from the west abutment to the second pier in order to channelize the cooling water flow in the lined portion of the canal. This wall is also recommended to protect the No. 1 and No. 2 piers against scour inasmuch as the tops of these pile caps are at elevation minus 7.65 m.s.l.

G. SEQUENCE OF CONSTRUCTION

27. General. - A comprehensive study of the overall sequence of construction of the Fox Point Hurricane Barrier was made with regard to the operational requirements of the Narragansett Electric Company. Since the operation of the Manchester Street and South Street generating stations is dependent upon a continuous supply of clean cooling water, the installation of the cooling water canal wall with its associated dredging and refill and the completion of the three discharge flume extensions will be required as the first order of construction. This procedure further requires that the west abutment (river section) be constructed after completion of the main barrier pumping station which will house the permanent cooling water intake openings. To accomplish this a

temporary opening between the pumping station and west shore bulkhead in the vicinity of the breaker house must be provided to allow passage of cooling water during the construction phases of the several components of the main river barrier. The west side of the cofferdam installation for the barrier pumping station can serve the dual function of acting as a portion of the cooling water canal temporary downstream extension.

H. HYDRAULICS

28. General. - The hydraulic design of the cooling water canal is in many respects very closely related with the hydraulic design considerations of the main river barrier. The proposed schedule of operation of the barrier gates and the pumping station is integrally related with the operation of the cooling water canal. For more detailed information on "Hydrology" and "Hurricane Tidal Hydraulics" reference should be made to Design Memorandum No. 2 and Design Memorandum No. 4 respectively. Basic criteria and other data pertinent to the design of the cooling water canal are presented herein.

29. Available Data. - The following tide data was compiled from records of the U. S. Weather Bureau, the City of Providence, Department of Public Works and data furnished by the Narragansett Electric Company.

a. High Tides. - It is estimated from tide records, October 1885 to September 1938 and September 1956 to June 1958, that the frequency of high tides in the vicinity of the cooling water canal is as follows:

Frequency	Elevation m.s.l.
Once per week	+3.5
Once per month	+4.2
Once per year	+5.2
Once in 10 years	+6.2

b. Low Tides. - It is estimated from tide records, 1885 to 1923 and September 1956 to June 1958, that the frequency of low tides in the vicinity of the cooling water canal is as follows:

Frequency	Elevation m.s.l.
Once per week	-2.9
Once per month	-3.5
Once per year	-4.6
Once in 10 years	-5.5

30. Cooling Water Flow Rates. - The following cooling water flow rates were established as a result of conferences with the Narragansett Electric Company.

Location	Present	Future
Manchester Street Station	385 cfs	435 cfs
South Street Station	300 cfs	340 cfs
	200 cfs	225 cfs
Total	885 cfs	1,000 cfs

31. Operation Procedures. - The barrier gates would normally be open and all flow would go through them in the absence of a hurricane. The head loss, except to exceptional storms, would be only a few inches. For non-hurricane type of floods the tides will not be excessively high and the barrier gates will be left open. The pumps may be turned on, while the barrier gates are open, for unusually large flows and relatively high tides. The cooling water influent gates from the harbor would normally be completely open and the cooling water would enter from the harbor downstream of the barrier for the conditions described above. When the danger of a hurricane becomes imminent, the barrier gates would be closed, according to operating procedures to be established later, and the basin level behind the barrier would be maintained as nearly as practicable at elevation 0.0 m.s.l. Whenever the barrier gates were closed in anticipation of and during hurricanes, attendance of the cooling water intake gates from the harbor will be necessary. For low head differentials between the harbor level and the river level, the intake sluice gates could remain open and the cooling water discharge would be in turn discharged through the barrier pumps. For high harbor levels with respect to the river, the intake gates would be throttled sufficiently to produce a level within the canal below the maximum design differential of 2 feet between the canal level and the river level.

32. Relief Gates. - In the event that the intake gates from the harbor were not sufficiently throttled and inflows in excess of the usage (1,000 cubic feet per second) resulted, the water level within the canal would build up. This would result not only in large differentials of head against the canal wall but also in excessive canal velocities. In the event that the intake gates were over-throttled, the level in the canal would drop excessively, producing high canal velocities, a high differential head on the canal wall, and low submergence of the cooling water pumps. To preclude such occurrences, relief gates in the canal wall are required. Furthermore, whenever the barrier gates were closed during a hurricane and the river flow became such that three pumps could not keep pace with the inflow, the cooling water intake gates would be closed and cooling water would be taken from the river

through the relief gates. Because of the appreciable flow in the river at this time (about 5,000 cfs) and because such a flow would be of short duration, the possible adverse temperature and silting effects would be minor. The primary advantage of taking the cooling water from the river instead of the harbor would be that the amount of water being pumped into the harbor through the barrier pumping station would be lessened by the quantity being used by the cooling condenser system if supplied from downstream of the barrier. In the event that the river inflow increased further, so that all five pumps would become necessary, this lessening of the quantity being pumped would be extremely helpful in controlling the water level in the pool behind the barrier. Summarizing, gates from the Providence River to the cooling water canal upstream of the barrier are necessary to prevent excessive differential head on the canal wall in either direction and to allow the use of river water during periods of high river inflow.

33. Functioning of Relief Gates. - The relief gates will have automatic as well as manual operation features. The reasons for provision for manual operation are as follows:

a. To make repairs without interruption of cooling water service. Repairs to the canal wall, existing bulkhead or intake gate structures and excavation of accumulated sediment from the canal bottom may become necessary in the future. Repairs and excavations could be made by isolating canal sections by sheeting and taking cooling water through either the river or harbor intake gates or both.

b. Periodic manual operation as preventive maintenance to insure proper automatic operation.

c. To avoid excessive head losses in the cooling water canal for abnormally low tides, the gates from the river could be opened. However, since the head losses are small, the gain would be minor.

The reasons for automatic operation of the river influent gates are as follows:

a. In the event that the differential head between the canal enclosure and the basin behind the barrier tends to become excessive in either direction so that the canal wall is endangered, the river gates should open automatically. The opening should occur gradually to avoid excessive velocities which may scour the canal bottom or result in a surge.

b. The minimum elevation within the canal could become very low in absence of the river gates since the water level within the canal may drop rapidly as the influent harbor gates are throttled. To prevent air entrainment of the cooling water pumps, the river influent gates should open automatically.

34. Size, Type and Location of Relief Gates. -

a. Size and Type. - Since relief gates to the cooling water canal are essential, their size, number, type and location were considered next. Several types of gates were considered including tide gates, vertical lift sluice gates and shutter gates. Based on cost and design considerations and operational requirements, the simple hinge mounted tide or flap gate was selected as best suited and most economical for the intended function. The advantages and disadvantages of the various gate types were thoroughly discussed with the Narragansett Electric Company and the final selection was made with their full approval. To accommodate the basic canal wall construction and to minimize the additional structural framing required for the gates, the individual gate opening size has been selected as 6 feet wide by 12 feet high. Since the differential in head can develop in either direction, two sets of four gates each providing a flow area of 288 square feet are tentatively planned to be provided at a spacing of 10 feet on center. One set will operate to allow inflow into the cooling canal from the Providence River and the other set will operate to allow discharge from the cooling canal into the Providence River. The flap gates will be designed such that each set will open at a head differential of one foot. Lower operating heads are not recommended as the flap gates would be too sensitive and could be actuated by wave action and result in constant metering of flow. This would tend to defeat the basic purpose of the cooling water canal. Based on the occurrence of low tides and the design requirement that these flap gates be installed such that the entire gate must be totally submerged under all operating levels to assure proper operation for the design head differentials, the lower linkage of the flap gate is proposed to be set at elevation minus 5.0 m.s.l. Discussions with gate manufacturers deemed it inadvisable to set or extend the hinges above low water. Special fittings would be required for such a provision. The use of bronze or stainless steel fittings should provide adequate corrosion resistance. The gates would also be inclined to the vertical to assure seating and to reduce the buoyant weight required to assure closure below the operating head. For the infrequent manual operations, a lifting eye hook with a short piece of stainless steel cable extended and secured above tide levels will be provided. The flap gates as schematically proposed on Plate No. 11-10 are shown to be of timber construction. The final design of the relief gates to satisfy the one foot head operating differential will be based on the results of model tests. The amount of gate opening will be a function of head differential and the flow will depend on the size of opening that will develop around the sides of the gates. A one foot head of differential will produce a flow velocity of about 8 feet per second. Higher head differentials will produce higher velocities, although some head will be lost in "pushing" the gate open. It is virtually impossible to calculate a precise rating curve for the operation of these flap gates. The use of model testing will permit the establishment of the flow characteristics to satisfy the design heads and flows and may result in some change in the size or number of gates and final choice of construction material for the relief gates.

b. Location. - The two sets of four gates each will be located along a straight tangent section of the cooling canal wall between the Manchester Street and South Street station intakes, south of the Point Street Bridge, as shown on Plate No. 11-10. This location between the two generating stations would limit the flow north of the Manchester Street intake to about half of the total flow at all times. This is extremely helpful in limiting the required flow area under the Point Street Bridge where expensive underpinning or other protective measure might otherwise be required for greater flow requirements. Preference for this location for the gates was also expressed by the Narragansett Electric Company because of sewage overflow discharge from the Elm Street sewer in the vicinity of the South Street Station.

35. Summary of Velocities. -

a. Assumptions. -

(1) Tide level; elevation minus 6.0 m.s.l. (elevations within the canal range from minus 6.3 m.s.l. to minus 6.6 m.s.l. due to hydraulic losses).

(2) Future flows; Manchester Street 435 cfs, South Street 340 cfs and 225 cfs.

(3) Side slope is a 2 on 1 with a variable elevation at existing bulkhead.

b. Summary. - For locations of sections, see Plate Nos. 11-2 and 11-3. For details of sections, see Plate Nos. 11-12 through 11-16.

Section	Station	Flow cfs	Minimum Bottom Elevation m.s.l.	Flow Area ft^2	Velocity ft./sec.
Intake bay	--	1,000	-18.0	304	3.29
1	0+52	1,000	-25.0	1,269	0.79
2	1+02	1,000	-25.0	1,205	0.83
3	1+52	1,000	-25.0	1,127	0.89
4	2+02	1,000	-25.0	1,169	0.86
5	2+51	1,000	-25.0	1,278	0.78
6	3+00	1,000	-25.0	1,095	0.91
Manchester St.Sta. Intake	--	435	-19.5@conc.pad bet. piles	440	0.99
7	3+48	565	-25.0	889	0.64
8	3+98	565	-25.0	979	0.58
9	4+53*	565	-25.0	784	0.72
10	4+98	565	-25.0	913	0.62
11	5+58**	565	-25.0	626	0.90
12	5+98	565	-25.0	789	0.72
13	6+48	565	-22.5	852	0.66
14	6+95	565	-20.0	915	0.62
15	7+38	565	-20.0	1,266	0.45
16	7+82	565	-20.0	1,540	0.37
17	8+28	565	-20.0	1,850	0.31
18	8+77	565	-20.0	1,724	0.33
19	9+26***	565	-20.0	417	1.35
20	9+76	565	-20.0	1,656	0.34
21	10+22	565	-20.0	1,461	0.39
22	10+60	565	-22.5	1,222	0.46
23	11+00	565	-25.0	966	0.59
24	11+57****	565	-26.0	568	0.99
25	11+97	565	-28.0	910	0.62
26	12+47	565	-28.0	1,025	0.55
27	12+97	565	-28.0	1,122	0.50
South St. Sta.So. Intake	--	340	-25.5@conc.pad 336@harbor line		1.01
28	13+47	225	-28.0	1,025	0.22
29	13+97	225	-28.0	978	0.23
30	14+47	225	-28.0	1,111	0.20
South St. Sta.No. Intake	--	225	-27.5@conc.pad 316@intake ports		0.71

* Manchester St.Sta.-So.Discharge Flume
**Manchester St.Sta.-No.Discharge Flume
*** Point St. Bridge
****South St.Sta.-So. Discharge Flume

c. Effect of Tidal Flows. - The maximum velocities expected within the cooling water canal have been summarized above. These velocities have been considered at the extreme low tide of elevation minus 6.0 m.s.l. and the maximum cooling water demand use of 1,000 cfs. Additional inflow is possible due to the effect of a rising tide in filling the canal and resulting in a rising water surface area within the cooling water canal. However, at the lowest point of the low tide cycle the water surface will be nearly constant or else changing very slowly so that the tide effect would be negligible. At higher tide levels the increase in depth of flow will reduce the canal velocities below those computed at a 1,000 cfs flow at elevation minus 6.0 m.s.l., in spite of some increase in total flow due to the rising tide. The maximum flow velocities under the discharge flumes, however, will be increased by the effect of the rising tide whenever the bottom of a discharge flume extension is submerged. It is estimated that for the 2.6 acres of the cooling water canal surface area, the normal rate of rising tide of about one foot per hour will increase the inflow by approximately 32 cfs, a 2-foot per hour rise occurring about once a year will increase the inflow by about 64 cfs, and a 4-foot per hour rise occurring during an unusual hurricane tide condition will increase the inflow by about 128 cfs. For the three constrictions under the discharge flumes, the increases in flow will be in proportion to the surface area of the cooling water canal behind the particular discharge flume extensions. The following table summarizes the conditions under the respective discharge flume extensions as calculated for the tide elevation of minus 6.0 m.s.l. and constant tide level and for rising tides with elevations which could range from about minus 4.5 m.s.l. to plus 5.0 m.s.l.

DISCHARGE FLUME EXTENSIONS

Rate of Tide Rise	Manchester-South			Manchester-North			South St.-South		
	Q	A	V	Q	A	V	Q	A	V
ft/hr.	cfs	s.f.	ft/sec.	cfs	s.f.	ft/sec.	cfs	s.f.	ft/sec.
0	565	771	0.73	565	558	1.01	565	538	1.05
1	589	867	0.68	587	558	1.05	570	559	1.03
2	613	867	0.71	609	558	1.09	575	559	1.04
4	661	867	0.76	653	558	1.17	585	559	1.05

36. Cooling Water Canal - Head Loss Computations. -

a. General. - The head loss computations for the cooling water canal are hereinafter presented. These head losses have been computed for both the intake or access bay and the cooling canal proper.

b. Assumptions. -

(1) Tide level; elevation minus 6.0 m.s.l., about once in 20 years.

(2) Flow; 1,000 cfs (565 cfs to South Street Station).

c. Computations. -

Access Bay

Entrance loss:

Width = 26 feet. Invert = -18. Flow depth = 11.76.

A = 26x11.76=306 $feet^2$. V = 1,000÷306=3.27 feet per sec.

$V^2/2g$=0.17. K=0.50. H_L=0.50x.17=0.08.

En.Gr.= -6.00-.08= -6.08.

Hyd.Gr.= -6.08-.17= -6.25.

Approach Channel:

W = 28 feet. A = 28x11.75=330 $feet^2$.

V = 1,000÷330=3.03 feet per sec. $V^2/2g$=0.14.

H_L = .03 (stop-log slots, entrance pier and friction).

En.Gr.= -6.08-.03= -6.11.

Hyd.Gr.= -6.11-.14= -6.25

Gradual contraction to gates:

W = 20 feet. A = 20x11.56=231 $feet^2$.

V = 1,000÷231=4.33 feet per sec. $V^2/2g$=0.29.

K = 0.10. H_L = .29x.10=.03.

En.Gr. = -6.11-.03= -6.14.

Hyd.Gr.= -6.14-.29= -6.43.

Gradual expansion from gates:

$W = 26$ feet. $A = 11.68 \times 26 = 304$ feet^2.

$V = 1{,}000 \div 304 = 3.29$ feet per sec. $V^2/_{2g} = 0.17$.

$K = 0.05$. $H_L = .29 \times .05 = .01$.

En.Gr. $= -6.14 - .01 = -6.15$.

Hyd.Gr. $= -6.15 - .17 = -6.32$.

Friction loss:

$P = 72.7$. $R = 4.18$. $R^{2/3} = 2.60$. $n = .013$.

$V = \frac{1.49}{n} R^{2/3} S^{1/2} = 3.29 = \frac{1.49}{.013} \times 2.60 \times S^{1/2}$.

$S = .00013$. $H_f = 91 \times .00013 = .01$.

En.Gr. $= -6.15 - .01 = -6.16$.

Hyd.Gr. $= -6.16 - .17 = -6.33$.

Exit loss:

$V = 3.29$ feet per sec. $V^2/_{2g} = 0.17$.

$K = 1.0$. $H_L = .17$.

En.Gr. $= -6.16 - .17 = -6.33$.

Hyd.Gr. $= -6.33 - .01 = -6.34$

Cooling Water Canal

Channel to Manchester Street Intake:

V min. $= 0.83$ ft/sec. $V^2/2g = .01$ ft.

V max. $= 0.91$ ft/sec. $V^2/2g = .02$ ft.

Friction loss:

$P = 94 \quad R = 11.75 \quad R^{2/3} = 5.16 \quad n = .025$

$V = \frac{1.49}{n} R^{2/3} S^{1/2} = 0.91 = \frac{1.49}{.025} \times 5.16 \times S^{1/2}$

$S = .000009 \quad H_f = 250 \times .000009 = .002$ ft.

Piles, turbulence at intake and friction $H_L = .04$ ft.

En.Gr. = -6.33 - 0.4 = -6.37

Hyd.Gr. = -6.37 - 0.2 = -6.39

Manchester Street Intake to Manchester Street North Discharge:

V min. = 0.72 ft/sec. $V^2/_{2g} = .01$ ft.

V max. = 1.0 ft/sec. $V^2/_{2g} = .02$ ft.

Friction loss:

$P = 147 \quad R = 3.82 \quad R^{2/3} = 246 \quad n = .025$

$V = \frac{1.49}{n} R^{2/3} S^{1/2} = 1.0 = \frac{1.49}{.025} \times 2.46 \times S^{1/2}$

$S = .00005 \quad H_f = 247 \times .00005 = .01$ ft.

Piles, discharge flumes and friction $H_L = .03$ ft.

En.Gr. = -6.37 - .03 = -6.40

Hyd.Gr. = -6.40 - .02 = -6.42

Manchester Street North Discharge to Point Street Bridge:

V min. = 0.31 ft/sec. $V^2/_{2g} = .001$ ft.

V max. = 1.0 ft/sec. $V^2/_{2g} = .016$ ft.

Pier, bends and friction $H_L = .03$ ft.

En.Gr. = -6.40 - .03 = -6.43

Hyd.Gr. = -6.43 - .02 = -6.45

Under Point Street Bridge:

V min. = 0.33 ft/sec. $V^2/2g$ = .001 ft.

V max. = 1.35 ft/sec. $V^2/2g$ = .03 ft.

Friction loss:

P = 100 R = 4.17 $R^{2/3}$ = 2.6 n = 0.025

$$V = \frac{1.49}{n}R^{2/3}S^{1/2} = 1.35 = \frac{1.49}{.025} \times 2.6 \times S^{1/2}$$

S = .00008 H_f = 100 x .00008 = .01 ft.

Entrance loss	= 0.5 x .03	= .02
Exit loss	= 1.0 x .03	= .03
Pier and bends		= .04
Friction		= .01
	H_L	= .10 ft.

En.Gr. = -6.43 - .10 = -6.53

Hyd.Gr. = -6.53 - .03 = -6.56

Point Street Bridge to North Intake South Street Station:

V min. = 0.20 $V^2/2g$ = .0006 ft.

V max. = 0.84 $V^2/2g$ = .01 ft.

Friction loss:

P = 77 R = 8.8 $R^{2/3}$ = 4.3 n = 0.025

$$V = \frac{1.49}{n}R^{2/3}S^{1/2} = 0.84 = \frac{1.49}{.025} \times 4.3 \times S^{1/2}$$

S = .00001 H_f = 500 x .00001 = .01 ft.

Piles, bends, friction and turbulence at intakes H_L = .03

En.Gr. = -6.53 - .03 = -6.56

Hyd.Gr. = -6.56 - .02 = -6.58

Approximate drop in water surface = 0.60 ft.

0.35 ft. in the Access Bay

0.25 ft. in the Canal

I. COOLING WATER CANAL WALL - CONSTRUCTION TYPES

37. General. - Prior to the preparation of this design memorandum a special study was made of the various types of construction for the wall separating the cooling water canal from the Providence River. This study endeavored to determine whether the wall should be constructed of steel sheet piling, prestressed concrete sheet piling, prestressed concrete cylindrical pipe piles, or of steel H-pile soldier beams and timber panels. Also, a wall of completely timber construction was studied; however, due to the magnitude of the design loads, this type of construction was found to be unfeasible. A summary of the advantages and disadvantages of the several feasible types of construction and their comparative cost estimates are presented hereinafter. These cost estimates include only the principal wall items. Common items to any wall type such as the relief gates, access bridge, utility extensions, inner deflector wall, dredging and refill are not included. The estimates are presented for comparison only and would be subject to adjustment during preparation of final design. See the appendix for the breakdown of major items.

38. Steel Sheet Piling. - This type of construction consists of a single line of steel sheet piling driven to sufficient depth to develop support in the existing sands and silts, a single wale member located near mean sea level, and battered H-piles spaced uniformly along the wall, connected to the wale member to provide lateral support.

a. Advantages. - The advantage of this type of wall construction lies in the fact that a large portion of the barrier construction requires the use of temporary cofferdams and steel sheeting so that the contractor must be equipped for this type of work and this might result in lower on-site costs for mobilization and demobilization. In view of the fact that the canal work must be constructed first, there would be no saving in terms of possible temporary use of the sheet piles. Due to the fact the steel sheeting would be continuous below the canal bottom, the possibility of seepage resulting from unbalanced hydrostatic pressures would be reduced.

b. Disadvantages. - Long steel sheets will generally be required for the entire length of canal wall as a certain minimum penetration is required for structural stability. Driving conditions are expected to be erratic along the length of wall and in some instances, the minimum required penetration may be difficult to achieve. This type of construction cannot be permitted in the vicinity of submarine cables and other submerged utilities. This would require the use of an alternate type of construction in such areas. The effective application of protective coatings would be difficult and in some respects wasteful as the very method of installation would leave the condition of the coating at the interlocks very doubtful in terms of the long life expectancy desired. Because this type of construction entails the greatest amount of steel, it requires the greatest expenditure of money to provide cathodic protection. In the event of future repairs and replacement, it represents difficult construction problems involving extraction and redriving of an integral type of structural system.

c. Construction Cost. - The construction cost of the steel sheet piling scheme for the cooling water canal wall is estimated to be $854,661.

39. Prestressed Concrete Sheet Piling. - This type of construction is similar to the steel sheet pile type except that prestressed concrete sheet piling has been substituted for steel sheet piling.

a. Advantages. - The singular major advantage of this type of wall is the reduction of the amount of steel that would require cathodic protection.

b. Disadvantages. - The use of long heavy individual pile units would present some construction difficulties. The objections raised regarding the steel sheet pile wall type apply equally well for this alternate. In addition, some serious questions can be raised regarding the effectiveness of the simple interlock in transferring shear. The control of drift during driving would be much more difficult for this type of unit than a steel sheet using a high strength interlock.

c. Construction Cost. - The construction cost of the prestressed concrete sheet piling scheme for the cooling water canal wall is estimated to be $886,219.

40. Prestressed Concrete Cylindrical Pipe Piles. - This study entailed the investigation of a self-sustaining type of wall construction, wherein a section of large section modulus would be utilized without added structural members for lateral support. The basic section would consist of a 54-inch prestressed concrete cylindrical pipe pile at 5-foot-6-inch centers with a precast concrete filler piece.

a. Advantages. - The major advantages of this type of wall construction are as follows. As previously stated, no wale systems or batter piles are required. The installation requires no underwater connections. Being constructed entirely of concrete, there would be no need for any cathodic protection. The application of a suitable protective coating should give a long life expectancy. The thickness of concrete cover could be increased to give added protection to the prestressing cables. The manufacture of these units is such that an extremely dense and high strength concrete of uniform quality can be achieved. From an aesthetic point of view, this type of wall would provide a pleasing appearance.

b. Disadvantages. - The disadvantages of this type of wall construction are as follows. Installation of these cylindrical units to the depths required for stability would involve considerable jetting, operational cleanouts and pre-excavation to achieve the minimum penetrations. This would result in considerable disturbance of the organic bottom sediments unless confined within temporary enclosures. Modification of the wall type would be necessary in the vicinity of the submarine cables and other submerged utilities. Due to heavy and cumbersome nature of the units, the use of this wall type under the Point Street Bridge would be extremely difficult unless an alternate wall type were used in this area.

c. Construction Cost. - The construction cost of the prestressed concrete cylindrical pipe pile scheme for the cooling water canal wall is estimated to be $1,139,678.

41. Steel H-pile Soldier Beams and Timber Panels. - This type of construction consists of a spaced "soldier" beam or master vertical pile framed to a battered pile of elevation 0.0 m.s.l. The space between each soldier H-pile is filled with a creosoted timber panel which extends into the river bed a sufficient depth to eliminate seepage under the wall section at times of differential head and to retain the granular refill.

a. Advantages. - The advantages of this type of construction are numerous. This type of wall system allows the maximum of flexibility in avoiding submerged utilities. The width of the insert panels can be varied to suit field conditions after driving of the soldier and batter units. The soldier and batter units can be designed for irregular spacings that may be required to avoid submerged utilities. This feature is especially helpful in avoiding the 115,000-volt and 11,000-volt submarine cables. The total amount of submerged steel to be protected cathodically is reduced. This type of wall construction is essentially a variation of the first type considered in an attempt to overcome some of the disadvantages and employ some less expensive materials. It is based on employing a spaced "soldier" beam or master vertical pile with a batter pile to resist horizontal loads. The space between each load-resisting unit is filled with a creosoted wood panel. The first cost of the timber panels is low and should require little protection except for creosoting. Should eventual replacement be required, it can be performed very easily without disrupting the main structural system.

b. Disadvantages. - The disadvantages of this type of wall construction are as follows. The driving of the batter and vertical pile units will require rather close tolerance. It is planned to drive the batter first, spring it up and aside, then drive the vertical pile, scribe the batter, cut it off under water and secure the special connection. This method of installation was discussed with marine contractors and proven feasible. However, alternate methods of installation are possible and final choice will be left to the contractor's option.

c. Construction Cost. - The construction cost of the steel H-pile soldier beam and timber panel scheme for the cooling water canal wall is estimated to be $648,080. This estimate has been developed in g reater detail since it is the adopted method of construction.

42. Selected Type of Construction. - In studying the relative advantages and disadvantages of the four basic types of construction, the steel H-pile soldier beam and timber panel scheme offers more flexibility in initial installation and future replacement and is definitely competitive on an economic basis. Accordingly, this system will be used for the construction of the cooling water canal wall.

J. COOLING WATER CANAL WALL, FLAP GATES, DISCHARGE FLUME EXTENSIONS AND UTILITY EXTENSIONS - STRUCTURAL

43. Purpose. - This section of the design memorandum presents the design criteria, basic data and assumptions used in developing the structural design of the various components of the Cooling Water Canal. Subsequent paragraphs present loadings, methods of design and detailed descriptions of each of the appurtenant structures.

44. Scope. - Hydrostatic loadings, lateral earth pressure criteria, stability investigations, design of structural steel, timber and reinforced concrete sections as well as a statement of the foundation pile design are included herein.

45. Design Criteria. -

a. General. - All working stresses will conform to those specified in Engineering Manual EM 1110-1-2101, "Working Stresses for Structural Design", dated 6 January 1958. Other design criteria is based on applicable parts of the Engineering Manual for Civil Works, Standard Practice for Concrete (Part CXX, October 1953).

b. Concrete. - Paragraph 15b of Design Memorandum No. 10 is applicable.

c. Reinforcement. - Paragraph 15c of Design Memorandum No. 10 is applicable.

d. Structural Steel. - Structural steel was designed for the working stresses of ordinary bridge and building steel (yield point 33,000 psi minimum), which conforms to the "Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings" issued by the American Institute of Steel Construction. Allowable working stresses conform to those given in the Engineering Manual for Civil Works for a basic stress of 20,000 pounds per square inch except as modified below.

(1) Vertical and Battered H-piles of Canal Wall. - The allowable working stress has been set at 24,000 psi.

(2) Temporary Flume Supports. - The allowable working stress has been increased 25 percent to 25,000 psi.

(3) Utility Extensions and Access Bridge. - These structures are laterally unsupported and have values of Ld/bt in excess of 600. The allowable working stresses have been reduced, therefore, in accordance with the formula:

$$fs = \frac{12{,}000{,}000}{Ld/bt}$$

e. Structural Timber. - Structural timber shall be Douglas fir, 1,450 f No. 1 and shall be designed for the following working stresses:

Extreme fiber in bending	1,450 psi
Tension parallel to grain	1,450 psi
Horizontal shear	120 psi
Compression perpendicular to grain	390 psi
Compression parallel to grain	1,200 psi

46. Basic Data and Assumptions. -

a. Controlling elevations (m.s.l.)

Top of canal wall	El. 5.0
Centerline of connection of vertical and battered H-piles	El. 0.0
Centerline of lower pin of flap gate	El.-5.0
Invert of Manchester St.Sta.No.Discharge Flume Extension	El.-4.65
Invert of Manchester St.Sta.So.Discharge Flume Extension	El.-2.65
Invert of South St.Sta.So.Discharge Flume Extension	El.-3.15

b. Loads. -

(1) Dead Loads. - The following unit weights for materials have been used:

Concrete	150 lbs.per cu.ft.
Steel	490 lbs.per cu.ft.
Timber	40 lbs.per cu.ft.
Granular refill	55 lbs.per cu.ft.(buoyant)
Organic silts (lower layer)	30 lbs.per cu.ft.(buoyant)
Existing sands and silts	55 lbs.per cu.ft.(buoyant)

(2) Live Loads. - The following live loads have been used:

Water (salt)	64.2 lbs.per cu.ft.
Wind (hurricane conditions)	30 lbs.per sq.ft.
Wind (normal conditions)	20 lbs.per sq.ft.
Snow	40 lbs.per sq.ft.
Design load on catwalk	50 lbs.per sq.ft.
Design load on access bridge	50 lbs.per sq.ft.

c. External Water Pressure. - External water pressure, as produced by the design differential head of 2 feet, has been applied to the cooling water canal wall for the full depth of the timber panels. Likewise, external water pressure has been accounted for in the analysis of the box sections of the discharge flume extensions.

d. Earth Pressure. - Lateral earth pressures applied to the cooling water canal wall have been determined in accordance with the accepted principles of modern soil mechanics.

e. Ice Pressure. - Ice pressure against the cooling water canal structures is not a factor.

f. Wind Pressure. - Paragraph 16h of Design Memorandum No. 10 is applicable.

g. Frost Protection. - Frost action on the cooling water canal structures is not a factor.

47. Cooling Water Canal Wall. -

a. Description. -

(1) Normal Treatment. - The cooling water canal wall generally consists of steel H-piles driven vertically at a spacing of 10 feet on centers with 8-inch thick creosoted timber panels

placed between the flanges of the H-piles. These timber panels extend from the top of the wall, elevation 5.0 m.s.l., to a point at least 5 feet below the proposed dredge line of the cooling water canal. The bottoms of the timber panels will be set at the required elevations by the application of vertical pressure and with the assistance of jetting, if necessary. Each vertical H-pile is braced by a battered H-pile extending from mean sea level into the storage basin of the Providence River at a slope in the ratio of one horizontal unit to 1.5 vertical units. A single wale member, running just above the joint of the vertical and battered H-piles, aligns and integrates the entire wall system. For details of the cooling water canal wall, see Plate Nos. 11-5 through 11-8.

(2) Special Treatment. - Appropriate details and modifications are provided at those points where the discharge flume extensions and special utility extensions pass through the cooling water canal wall as well as at the location of the flap gates. Several alternate methods of construction are also presented for that portion of the wall that passes over the 115 KV submarine cables of the Narragansett Electric Company, just north of the Point Street Bridge. Similar consideration was given to the presently inactive submarine cables in the vicinity of the Manchester Street cooling water intake structure.

b. Loadings. - The cooling water canal wall acts as a structural system at those times when the water levels inside and outside the canal are at different elevations. The magnitude of this hydrostatic differential head is limited by the system of flap gates. These gates, which will be discussed in detail in subsequent paragraphs, are so designed and positioned in the wall that the maximum head differential to which the wall may be subjected is 2 feet in either direction. The cooling water canal wall acts as a partition diaphragm, separating the cooling water in the canal from the water of the Providence River upstream of the barrier. During normal operating conditions, the cooling water canal wall is, theoretically, subjected to no unbalanced lateral forces, except for the small head losses within the canal.

c. Method of Design. - The cooling water canal wall has been designed as a flexible anchored bulkhead. The applied loads - i.e. the loads to be resisted, are the lateral hydrostatic forces against the creosoted timber panels and vertical H-piles due to the design differential head. Resisting these lateral forces are the vertical H-piles in flexure, which in turn are supported by the reaction of the battered H-pile at elevation 0.0 m.s.l. and by a reaction produced by the embedment of the vertical H-pile into the existing sands and silt.

The upper surface of the sands and silts generally occurs in the vicinity of elevation minus 40.0 m.s.l. The vertical H-piles will be driven through the existing sands and silts and penetrate the underlying till (elevation minus 70.0 m.s.l. plus or minus) for an estimated depth of approximately 2 feet. The reaction of the till against the end of the H-pile together with the passive resistance of the sands and silts against the leading flange of the H-pile combine to form a couple which develops a fixed-end condition (a point of zero angle change) at some point below the top of the sands and silts. A further assumption is made in designating the top of the sands and silts as the point of contraflexure (point of zero bending moment) in order to render this theoretically indeterminate structure statically determinate. From this point the design procedure consisted of computing the H-pile spacing that will produce a bending moment that can be resisted by the H-pile section at allowable stresses.

d. Design. -

(1) Vertical H-pile. - The main flexural member is a 14 BP 102 steel H-bearing pile, driven into the till and spaced at 10 feet on centers.

(2) Battered H-pile. - This supporting member is a 12 BP 74 steel H-bearing pile, extending into the storage basin at a slope of one horizontal unit to 1.5 vertical units and driven into the sands and silts for an embedded length not less than 25 feet for pull-out resistance under reverse loading. The selection of this section also considered providing a fairly rugged member to withstand the driving requirements in view of a considerable unsupported length.

(3) Timber panels. - The timber panels are 9 feet 9 inches long, 10 feet 4 inches high and 8 inches thick and are fabricated by bolting together 8 pieces of 8-inch by 16-inch nominal timber stock. For details of the fabricated unit, see Plate 11-9. The entire panel unit is creosoted as a protective measure against decay above water and possible attacks of marine borers below water.

(4) Wales. - The wale is a 12 WF 53 rolled section and is located just above the connection of the vertical and battered piles. As stated previously, its function is to align and integrate the entire system of the cooling water canal wall. An additional function of the wale member is to provide a continuous electrical conductor throughout the entire cooling water canal wall for the impressed current system of cathodic system discussed hereinafter.

e. Connection between Vertical and Battered H-piles. - High strength bolts have been employed in this connection detail as an aid in eliminating any alignment irregularities induced by the driving process. For complete details of this connection, see Plate 11-8. An alternate welded connection will be permitted.

48. Flap Gates. -

a. General. - A complete statement of the hydraulic design of the cooling water canal appears in Section H "Hydraulics" of this Design Memorandum. An important corollary of this hydraulic study is the fact that under normal operating procedures as well as under conditions of hurricane danger, if there were no gates in the cooling canal wall there could occur, for periods of varying duration, substantial differences between the water levels inside and outside the cooling water canal. The maximum possible differential head was determined as being in the order of 8 feet. Preliminary studies of the cooling water canal wall based on a differential head of 8 feet produced a design that could not be justified from an economic standpoint. After a thorough and complete review of this problem from a hydraulic and operational standpoint, it was decided to limit the differential head to 2 feet in either direction by the introduction of flap gates into the cooling water canal wall.

b. Size. - From hydraulic considerations, it was determined that four gates, each having an opening of approximately 72 square feet, should be provided for each direction for differential head relief. Accordingly, eight gates, each having openings 6 feet wide and 12 feet high, will be installed; four to provide relief from high water in the upstream storage basin portion of the Providence River, and four to provide relief from high water in the cooling water canal.

c. Location. - As previously noted for hydraulic and other requirements, it was decided that the optimum location for the bank of flap gates should be near the center of the cooling water canal. Accordingly, when the horizontal alignment of the cooling water canal wall was developed, a 90-foot tangent was provided just south of the Point Street Bridge. With H-pile spacings of 10 feet on centers, this alignment provides nine spaces of 10 feet each. The northerly four spaces will accommodate the bank of gates that will open into the cooling water canal. They are so located in order to be as far removed as possible from the large volumes of hot water being discharged from Manchester Street Station. The southerly four spaces will accommodate the bank of gates that will open into the storage basin from the cooling water canal. A single space of normal wall construction will separate the two banks of flap gates.

d. Operation. - As stated previously, the function of the flap gates is to limit the differential hydrostatic head to which the cooling water canal wall may be subjected. Each bank of four flap gates will be counterweighted such that they will begin to open at a differential head of one foot. The 2.0-foot head differential for which the cooling water canal wall has been designed, provides for the operating range of differential head.

(1) Satisfactory operation of the individual gate depends upon the weight of the gate and its counterweights remaining constant at all times. This can only be assured if the gate is totally submerged under all conditions of tidal variations. For this reason, the lower hinge of all the gates has been set at elevation minus 5.0 m.s.l.

e. Fabrication. - The actual gate that has been presented in this Design Memorandum for use in the cooling water canal wall has been developed through consultation with a manufacturer of marine gates and machinery. The gate itself is a 6-inch thick timber panel composed of 6-inch by 12-inch stock, bolted and keyed together in much the same manner as the creosoted timber panels of the cooling water canal wall. In a closed position, the gate will seat against a timber frame which is bolted to a structural steel frame. The steel frame is so fabricated that the gate, when closed, is inclined from the vertical toward the direction of flow. As previously noted, the final design of the gates will be based on the results of model tests.

(1) Hinge Detail. - The hinge detail of the flap gate incorporates a "2-pinned link" which insures complete closure of the flap gates against the timber frame in the event of slight irregularities or uneven swelling in the gate or its frame. The hinges are bolted to a horizontal steel member which in turn is bolted to the flanges of the vertical H-piles. For tentative details of the flap gate assembly see Plate 11-10.

(2) H-pile Alignment. - Satisfactory operation of the cooling water canal and the structural integrity of the cooling water canal wall require that the flap gates function properly. Like any mechanism, these gates must be installed properly if they are to function as planned. Since the eight flap gates are placed between and supported by ten vertical H-piles, it is imperative that these H-piles be aligned with more precision than would ordinarily be necessary. Therefore, to facilitate installation of the flap gates, special driving techniques should be employed in placing these ten H-piles in order to insure greater than normal precision in vertical and horizontal alignment.

f. Catwalk and Access Bridge. - To provide for occasional maintenance and operation drills of the flap gates, a 3-foot wide catwalk structure has been provided along the 90-foot length of cooling water canal wall that accommodates the gates. Connecting this catwalk to the Narragansett Electric Company shore property is an access bridge spanning approximately 95 feet across the cooling water canal. For the location and details of the catwalk and access bridge see Plates 11-10 and 11-11. An alternate study was made of providing the access from the Point Street Bridge along the top of the cooling water canal wall, but this was found less desirable from an operational standpoint.

49. Alternate Wall Construction in Vicinity of Submarine Cables. -

a. General. - A bank of eight high voltage submarine cables extends across the Providence River just north of the Point Street Bridge. These cables are referred to as "115 KV Submarine Cables" in this and other sections of this Design Memorandum. These cables are the property of the Narragansett Electric Company and are considered by them as being of prime importance to their operations. Accordingly, the installation of the cooling water canal wall in the area requires special attention.

b. Alternate Treatment of Cooling Water Canal Wall. - The proposed cooling water canal wall passes directly over the submarine cables approximately 90 feet north of the Point Street Bridge. The exact location of these submarine cables is not known. It is entirely possible that the proposed normal method of construction of the cooling water canal wall will not be adaptable in this area once the exact location of the cables is determined by field diver survey. Anticipating this possibility, an alternative method of construction for the cooling water canal has been developed. For a presentation of this alternative method see Plate 11-9.

c. Inner Deflector Wall. - As previously stated in other sections of this Design Memorandum, the irregular horizontal alignment of the cooling water canal in the vicinity of the Point Street Bridge is due to the necessity of avoiding the 115 KV submarine cables which are present in this area. The width of the cooling water canal in this area, as determined by hydraulic criteria, extends from the cooling water canal wall to Pier No. 2. The area between Pier No. 2 and the west abutment is not considered part of the cooling water canal. It is considered unwise and potentially dangerous to the submarine cables to attempt an excavation and refill operation in this area. Nevertheless, unless some means is made available to isolate this area, it would, in fact, become part of the canal system. The existing organic silts would then be disturbed by the canal flow and thereby contaminate the cooling water being provided the South Street Station.

(1) In order to interrupt free canal flow through this sensitive area, a baffle called the "Inner Deflector Wall" will be constructed along the south fascia of the Point Street Bridge between the west abutment and Pier No. 2. The construction of the inner wall will be identical to that of the cooling water canal wall except that the battered H-pile will be eliminated. This is possible because of the absence of any differential hydrostatic head. The inner deflector wall is, in effect, a simple cantilever whose support is provided by the embedment of the vertical H-pile.

(2) At Pier No. 2 the inner wall will incorporate special details to effect an adequate closure. Likewire, at the west abutment, appropriate details will be employed to close the wall and deflect the discharge of the west abutment storm sewer into the cooling water canal. At this location, one opening in the deck of the Point Street Bridge will be required to install one pile that will accommodate the angle change in the inner deflector wall and allow a positive return into the west abutment. This closure is essential in order to channelize any flow from the aforementioned storm sewer from under the Point Street Bridge. For complete details of the Deflector Wall, see Plate 11-9.

50. <u>Discharge Flume Extensions</u>. -

a. <u>General</u>. - Satisfactory operation of the generating stations of the Narragansett Electric Company requires that the hot water presently being discharged into the Providence River from three existing flumes terminating at the shoreline be extended across the proposed cooling water canal and discharged into the upper basin portion of the river. Of these three flumes, two discharge hot water from generating units located in the Manchester Street Station, and one discharges hot water from a similar unit located in the South Street Station. The second unit for the South Street Station is located north of the terminus of the cooling canal and therefore need not be considered for extension.

b. <u>Description</u>. - The three discharge flume extensions are all similar in design and method of construction. All three are proposed to be constructed "in the dry" in dewatered cofferdams. They differ only in the specific details required by the varied conditions encountered at the existing flumes. Basically, the discharge flume extensions consist of the following:

(1) A reinforced concrete box flexural section which acts as the flume extension.

(2) An inboard and outboard pile cap which support the flume extension.

(3) Specific details and construction to effect a connection with the existing flume.

Each flume extension will be considered separately in subsequent paragraphs.

c. Loading. - The discharge flume extensions are basically simple beam structures spanning from inboard pile cap to outboard pile caps. The normal design load is, therefore, the weight of the flume itself plus a full complement of discharge water. In addition, strength is provided against the occurrence of horizontal loadings produced by hydraulic surges within the cooling water canal. The possibility of buoyant instability is theoretically impossible due to the position of the flap gates.

d. Foundation Piles. - The supporting foundation piles for the discharge flume extensions are proposed as concrete-filled cylindrical heavy walled pipe piles that will be driven open-ended. Due to the space limitations in the construction area and the need for battered piles, the selection of this type of pile over the H-pile, was considered advantageous because of orientation requirements. Furthermore, the piles within the canal influence the canal hydraulics and the circular section provides better flow characteristics. An alternative would be to utilize steel H-piles that would subsequently be encased in concrete. The design load on these piles is based on a 60-ton load during construction.

e. Manchester Street Station - North Discharge Flume Extension. -

(1) General. - This flume releases all the hot water effluent from generating unit No. 11 and part of the flow from generating unit No. 9. The actual discharge, while not exactly known, is estimated to be approximately 260 cfs. From the available record drawings, which are fairly complete, it is apparent that the existing flume consists of a timber roof and side walls and an invert mat of plain concrete. Photographs of this flume (see Plate 11-31) indicates that the exposed portion of this flume is in a seriously deteriorated condition. A complete evaluation of the present condition of this flume by field survey would only be possible if the generating units can be terminated a sufficient time to permit such a field investigation.

(2) Proposed Construction. - To satisfy the flow requirements, it is proposed that a discharge flume extension of the type previously described in this section and having a 6-foot 9-inch square opening be provided at this location. To minimize downtime during the construction of this flume extension, a temporary timber conduit, located between the two Manchester Street Station discharges,

has been employed as a by-pass. This device requires a minimum of downtime for generating unit Nos. 9 and 11 during construction. The flume extension will span approximately 62 feet across the cooling water canal. Due to operating requirements, the Narragansett Electric Company has requested that of the two discharge flumes at Manchester Street Station, the north discharge flume extension be constructed first. In conjunction with this construction, see Plates 11-21 through 11-23.

f. Manchester Street Station - South Discharge Flume Extension. -

(1) General. - This flume releases all the hot water effluent from generating unit No. 10 and part of the flow from generating unit No. 9. The actual discharge, while not exactly known, is estimated to be approximately 240 cfs. Although the available record drawings of the existing flume are incomplete and, at times, contradictory, it is apparent that the existing discharge is a reinforced concrete chamber that has been added to what was once a combination intake and discharge unit. A complete field survey would again be required in order to accurately determine existing conditions and this would entail a stoppage of the appropriate power generating units.

(2) Proposed Construction. - To satisfy the flow requirements, it is proposed that a discharge flume extension of the type previously described and having a 5-foot 6-inch square opening be provided at this location. This flume extension will span approximately 60 feet across the cooling water canal. Due to operating requirements, the Narragansett Electric Company has requested that construction of this flume extension be delayed until completion of the Manchester Street Station - north discharge flume extension. In conjunction with this construction, see Plates 11-18 through 11-20.

g. South Street Station - South Discharge Flume Extension. -

(1) General. - The existing south flume releases the hot water effluent from generating unit No. 7. The actual discharge is approximately 150 cfs. The existing discharge flume is located about 90 feet north of the Point Street Bridge. As noted previously, the cooling water canal wall at this location passes over the 115 KV submarine cables of the Narragansett Electric Company. If the existing flume were extended across the cooling water canal at this point it would be of excessive length and would involve additional pile driving in the vicinity of the submarine cables. Therefore, in view of these two undesirable conditions, it was deemed advisable to relocate the south discharge flume extension to a point approximately 135 feet north of the existing discharge. The available record drawings of this area are detailed and complete and give an excellent description of existing construction.

(2) Proposed Construction. - To satisfy the flow requirements, it is proposed that a discharge flume extension of the type previously described and having a 6-foot square opening be provided at this location. This flume extension will span approximately 50 feet across the cooling water canal. In conjunction with this construction, see Plates 11-24 through 11-26.

51. Utility Extensions. -

a. General. - Preliminary investigations incorporating a photographic survey indicated approximately 18 separate pipes and flumes discharging liquid effluents into the area that would be enclosed by the proposed cooling water canal. Of this number, four have been found to be capable of discharging objectionable effluents into the river. In view of the objectionable nature of the effluents of these four pipes it has been deemed necessary to extend them across the proposed cooling water canal. Two of the four existing discharges, because of their proximity, can be combined into one extension, thus making a total of three utility extensions.

b. Description. - The three utility extensions are all similar in design and method of construction. Each extension consists of the required size cast-iron pipe supported by and tied to a fabricated steel beam. The steel beam consists of two standard WF sections separated by transverse diaphragms and stiffened laterally by channel sections. The complete beam and pipe assembly is supported by a special spandrel beam at the cooling water canal wall and by a reinforced concrete pile cap adjacent to the existing shoreline. For details and design of the three utility extensions, see Plates 11-27 through 11-29.

c. Loadings. - The utility extensions are basically simple beam structures spanning from inboard pile cap to cooling water canal wall. The normal design load is, therefore, the weight of the pipe and beam assembly plus a full complement of discharge liquid. In addition to these gravity loads, strength and resistance to deflection must be provided against the possibility of horizontal loadings produced by hydraulic surges within the cooling water canal.

d. Foundation Piles. - Twelve-inch diameter treated timber piles of 15-ton design load capacity will be used for the inboard pile caps of the proposed utility extensions. These piles will be driven to the required bearing capacity in the granular materials underlying the organic silts.

e. Basic Data. -

(1) Utility Extension No. 1. -

Source of discharge:	Manchester Street Station Nos. 7 and 8 fuel oil tanks
Existing conduit:	12-inch cast-iron pipe
Invert elevation of existing conduit:	El. 5.3 m.s.l.
Proposed extension conduit:	12-inch flanged cast-iron pipe
Approximate span of extension:	90 feet

(2) Utility Extension No. 2. -

Source of discharge:	Manchester Street Station Fly-ash washer and Nuveyor discharge; and screen wash pump discharge
Existing conduits:	12-inch cast-iron pipe and 14-inch cast-iron pipe respectively
Invert elevations of existing conduits:	El. 4.8 m.s.l. and El. 4.6 m.s.l. respectively
Proposed extension conduit:	20-inch flanged cast-iron pipe
Approximate span of extension:	90 feet

(3) Utility Extension No. 3. -

Source of discharge:	South Street Station Screen wash pump discharge
Existing conduit:	18-inch by 12-inch timber box
Invert elevation of existing conduit:	El. 6.1 m.s.l.
Proposed extension conduit:	18-inch flanged cast-iron pipe
Approximate span of extension:	60 feet

K. CORROSION PROTECTION

52. Description and Requirements. - As a part of the overall study for the cooling water canal wall, an investigation was made of the river and bottom material conditions in the Providence River in the vicinity of the cooling water canal based upon Government-furnished chemical analyses of the river water and bottom sediments. The purpose of this study was to evaluate the existing conditions in determining requirements for cathodic protection for exposed steel construction and protective coatings for steel and other materials contemplated for use in the permanent construction.

53. Characteristics of River Water. - Pertinent characteristics of the river water are that it is ocean water diluted to a small extent and contains a considerable quantity of organic matter in the form of sewage. The condition of the river is such that the organic silt which comprises the uppermost strata of the existing river bottom is in the process of an anaerobic decomposition producing hydrogen sulfide. Chloride contents ranging between 10,500 ppm to 16,890 ppm and summer water temperatures of 60 degrees F. to 80 degrees F. have been reported. The water pH ranges from 7 to 8.3. For complete data on chemical and bacteriological characteristics and velocity and temperature variations refer to Design Memorandum No. 13 "Cooling Water and Corrosion Considerations".

a. A diluted ocean water is more corrosive than ocean water. This occurs as a result of the dilution of the ocean water's natural inhibiting action. Where organic wastes are present, organisms can thrive which manufacture a corrosive environment for steel. A study of the conditions in the area of the cooling water canal wall indicate a corrosion rate in the order of 5 to 50 mils per year on submerged steel. This corrosion may be decreased to a low value depending on economic considerations based upon the degree of protection desired.

54. Protective Coatings. - Since brackish water is an excellent electrolyte, the presence of mill scale on any submerged metal can lead to the formation of galvanic cells with subsequent development of localized pitting. Accordingly, any steel piling to be used for the proposed cooling water canal wall construction is to be sand-blasted to remove mill scale. In addition to this preliminary preparation, protective coatings will be used. The selection of recommended coating is limited due to the construction conditions under which the installation will be made and the environment of the installation. No coating can be guaranteed to stand up for the 30-year period established as the basis of estimating maintenance costs on this installation. However, an excellent coating for use on the steel piles is the coal tar epoxy resin type of coating now available. As an alternate, consideration can be given to the use of a vinyl red-lead coating or the use of a 2-part liquid rubber compound which cures to a durable, tough, flexible coating which has been used in marine applications including naval vessels. A well-proven protective coating consisting of three separate applications is also recommended. After surface preparation, an initial coating of insoluble zinc silicate is applied. A second coating consisting of a special synthetic resin is then applied as a primer. The final or third application of a dielectric vinyl coating completes the total coating. A great deal of consideration should also be given to coating the above-water portions of the steel piles which will be subject to the action of salt spray and atmospheric corrosion. A metallic coating such as sprayed aluminum or zinc can be utilized for the above-water areas. This design is based on the use of the coal tar epoxy resin below water and a sprayed aluminum for the above water portions.

a. Life Expectancy of Coatings. - In estimating maintenance costs for this installation for any fixed period of time, the evaluation of a life expectancy for any protective coating becomes an extremely difficult determination. This is due principally to the fact that the present river conditions will become changed by the construction of the barrier and the water within the cooling water canal will be chemically and biologically different from the water within the Providence River upstream of the barrier. It is anticipated that there will be an increase in salinity within the cooling water canal and probably a decrease in salinity in the still basin portion of the Providence River back of the barrier. In addition, the temperature of the water within the cooling water canal will be lower than the temperature within the still basin portion of the river due to the extension of the cooling water discharge flumes through the canal wall so that they will empty directly into the river. The excavation of the sulfide-bearing organic silt from within the cooling water canal will further alter corrosion conditions on the canal side of the wall. Accordingly it is virtually impossible to accurately predict life expectancies for the various protective coatings as there are too many variables which will influence service life.

55. Cathodic Protection. - Since corrosion rather than abrasion is the matter of principal concern and since the basic determinations indicate that the Providence River water can be expected to be more aggressive than sea water, there will be installed in addition to the protective coatings a cathodic protection system to provide additional protection to the submerged steel portions of the proposed cooling water canal wall. This requirement is based on the fact that once the cooling canal wall is in place, replacement of protective coatings below water will be virtually impossible and replacement of the entire installation within say a 30-year period of time will far exceed the first cost and maintenance cost of a properly designed and installed cathodic system.

a. Types of Cathodic Protection. - Two basic types of cathodic protection systems were considered for each of the principal wall types involving steel that were investigated in the special study that preceded this design memorandum. In studying the problem it was concluded that anodes should be placed on both sides of the wall to protect both sides. The preliminary investigations for both the galvanic type and impressed current type of cathodic systems for the soldier beam H-pile wall clearly indicated that the impressed current system of cathodic protection would prove to be the most economical based on both initial cost and maintenance and replacement costs for a 30-year period of time. The cost of power for the impressed current system was assumed to remain constant for this period in preparing the cost comparisons. The preliminary cost estimates for the two cathodic systems were based upon approximate costs of cathodic protection from past experience with similar situations. Adjustments of estimated costs were made as far as possible to suit the particular conditions at the cooling canal wall area. The preparation of these cost estimates were made in conjunction with nationally prominent corrosion consultants. It should be borne in mind that these preliminary estimates are approximate only and are based on limited investigations and without benefit of complete field surveys, tests, detailed plans or specifications. The estimates submitted, however, will cover a well-designed, properly installed and operating system having the life expectancy of the 30-year period.

b. Cost of Cathodic Protection. -

Galvanic		Impressed Current	
Initial Cost	$16,000.00	Total Cost*	$33,250.00
Life	7.5 years	Life	30 years
Annual Cost	$ 2,133.00	Annual Cost	$ 1,108.00
		Annual Power Cost**	$ 530.00
		Total Annual Cost	$ 1,638.00
Total 30-year Cost	$63,990.00	Total 30-year Cost	$49,140.00

* Installation and replacement required.
** Based on 1.8 cents per KWH

c. Adopted Type of Cathodic Protection. - The foregoing annual costs are arrived at by assuming straight line depreciation, neglecting capital costs, for the period of life expectancy. Based on the foregoing estimated costs, the impressed current type of cathodic protection system for the steel portion of the wall construction will be installed. The 30-year costs represent a very modest investment in terms of the total cost of the canal wall installation and there is little doubt as to the engineering need for this additional protection. If any of the previously mentioned organic type coatings are utilized, the voltage of the impressed current type of cathodic system should be limited to low values of about 1.2 to 1.5 volts maximum to prevent damaging the coating application.

L. MARINE BORER ACTIVITY

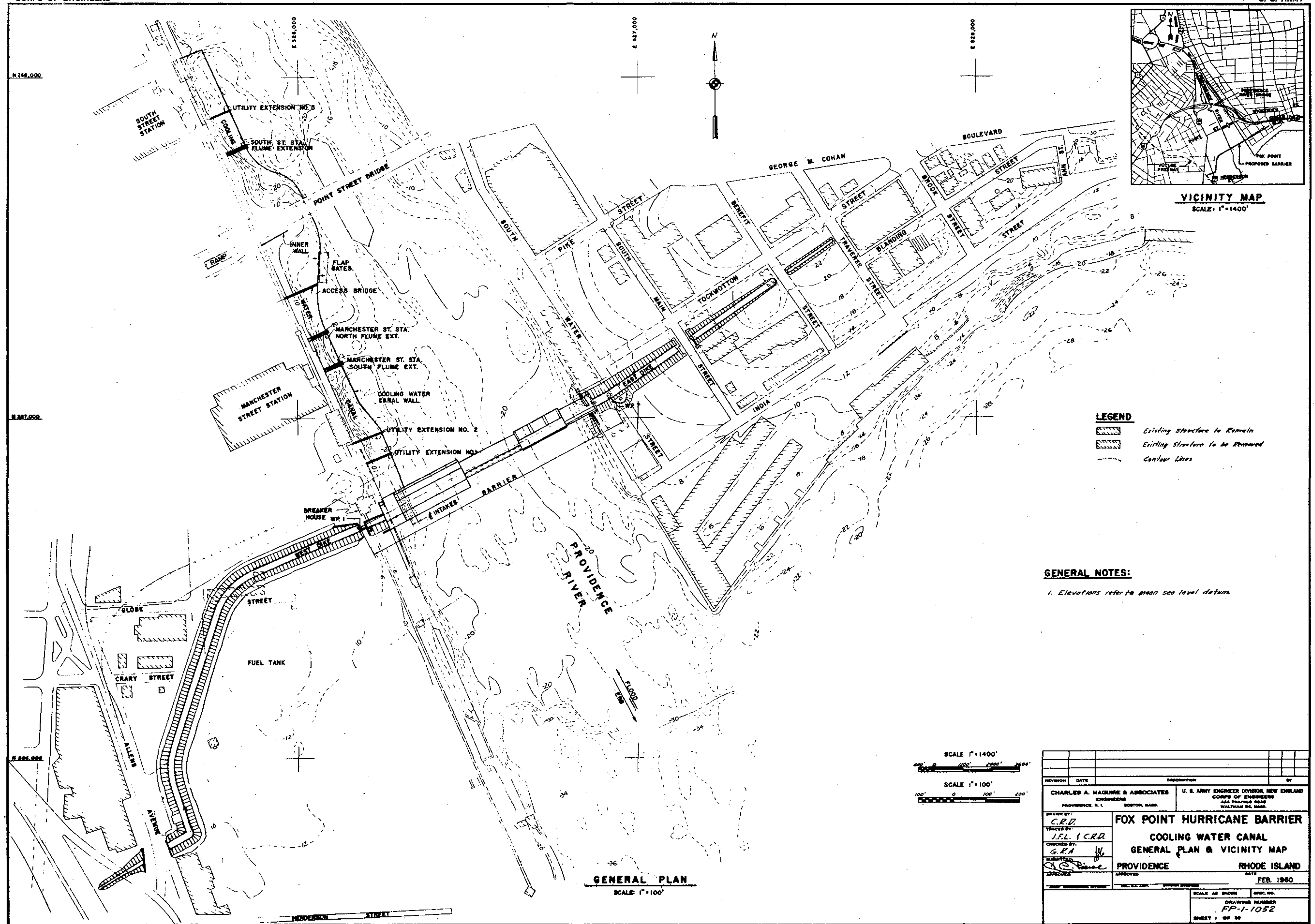
56. Description and Requirements. - Since the recommended type of cooling canal wall construction requires the use of a considerable area of wood, a separate study was made to obtain data on marine borer activity in the portion of the Providence River where the proposed canal wall will be installed. The recent chemical analysis of the Providence River water does not indicate a favorable environment for marine borers. However, the removal of the organic sediments within the cooling water canal and the intake of cleaner tidal waters into the canal downstream of the barrier may well improve the quality of the water that will be drawn into the cooling canal. A decrease in pollution can also be expected with future pollution abatement programs. This can result in a much more favorable future environment for marine borers.

57. Activity Tests. - A marine borer activity test board has been previously installed in the Providence River in the location of the Narragansett Electric Company at Manchester Street. Specific studies for evidence of activity by Limnoria and Teredo have been made since

1940*. The only evidence of marine borers since this board has been installed has been a trace attack of Limnoria in 1955 and 1958. There has been no evidence of Teredinidae. In view of the potential increase in marine borer activity, the use of treated wood is advisable. For waters where borers are or may become a problem, the William F. Clapp Laboratories recommend creosote coal tar solutions. These preservatives are covered by Federal specification TT-W-556c and AWPA-P-2. However, these specifications are not always considered adequate for marine installations. Where Limnoria are involved, tests have shown that a more permanent preservative can usually be obtained by the use of 70/30 creosote coal tar solutions. The minimum specific gravities will be raised from 1.025 to 1.030 and from 1.085 to 1.100 to provide the protection needed and reduce adulteration with less effective materials.

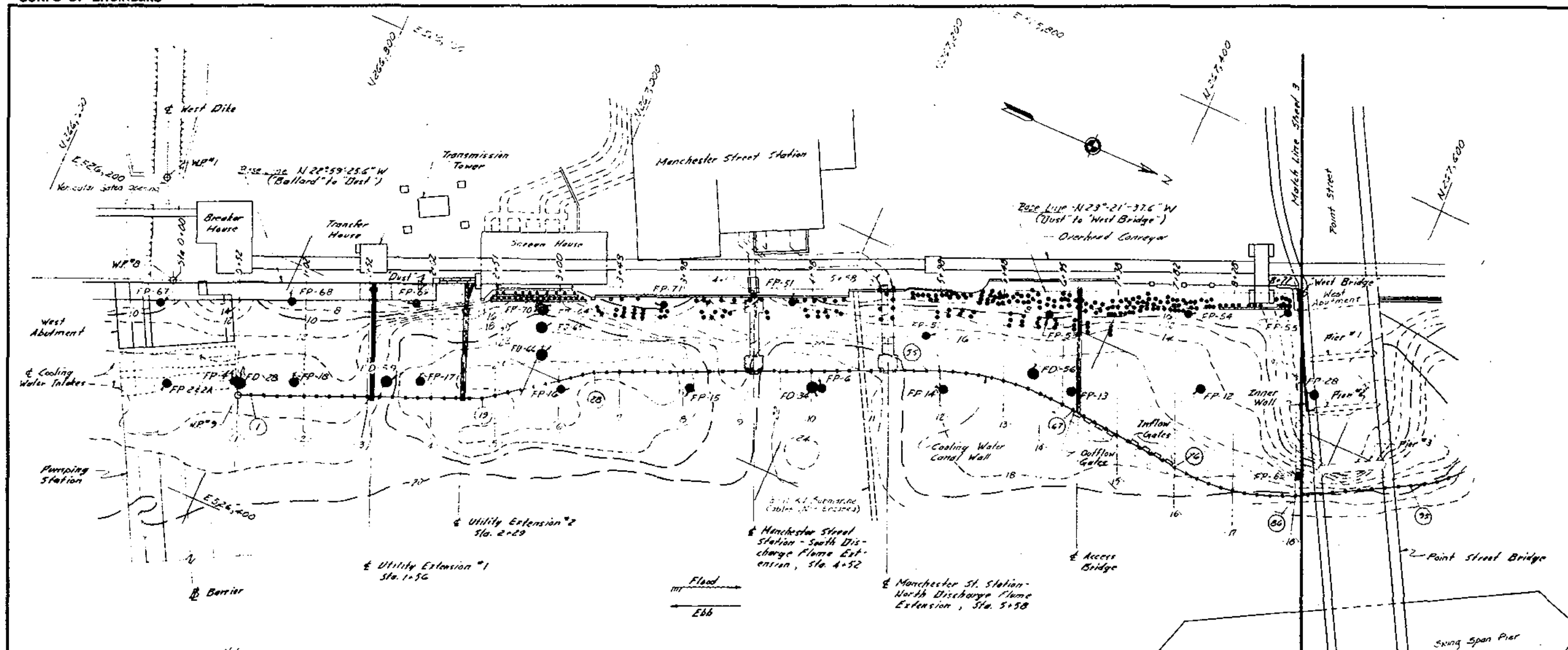
58. Preservative. - The durability of marine timber depends chiefly on two factors - the degree of penetration and the retention of the preservative. The penetration should be uniform and complete. Even in the absence of borers, deterioration of inadequately treated timber can be expected above the water line. The most commonly used specifications for treatment of marine piles are AWPA-C-3 and Federal specification TT-W-571c. These are generally satisfactory; however, it is recommended that the timber panels to be used for the cooling canal wall installation require rejection of all timber in any given charge if more than 10 percent of the timbers show inadequate penetration.

* Twelfth Progress Report on Marine Borer Activity in Test Boards operated during 1958. Compiled by Dorothy Brown Wallour.


VICINITY MAP
SCALE: 1" = 1400'
FOX POINT PROPOSED BARRIER
LEGEND
Existing Structure to Remain
Existing Structure to be Removed
Contour Lines
GENERAL NOTES:
1. Elevations refer to mean sea level datum.
SOUTH STREET STATION
UTILITY EXTENSION NO. 3
SOUTH ST. STA. FLUME EXTENSION
POINT STREET BRIDGE
INNER WALL
FLAP GATES
ACCESS BRIDGE
MANCHESTER ST. STA. NORTH FLUME EXT.
MANCHESTER ST. STA. SOUTH FLUME EXT.
MANCHESTER STREET STATION
COOLING WATER CANAL WALL
UTILITY EXTENSION NO. 2
UTILITY EXTENSION NO. 1
BREAKER HOUSE
INTAKES
BARRIER
EAST DIKE
WEST DIKE
PROVIDENCE RIVER
FUEL TANK
GLOBE STREET
CRARY STREET
ALLENS AVENUE
HENDERSON STREET
SOUTH WATER STREET
SOUTH MAIN STREET
PIKE STREET
TOCKWOTTON STREET
INDIA STREET
BENEFIT STREET
TRAVERSE STREET
BLANDING STREET
BROOK STREET
GEORGE M. COHAN BOULEVARD
FLOOD
EBB
SCALE 1" = 1400'
SCALE 1" = 100'
GENERAL PLAN
SCALE 1" = 100'
REVISION
DATE
DESCRIPTION
BY
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I.
BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.
DRAWN BY: C.R.D.
TRACED BY: J.F.L. & C.R.D.
CHECKED BY: G.R.A
SUBMITTED:
APPROVED
FOX POINT HURRICANE BARRIER
COOLING WATER CANAL
GENERAL PLAN & VICINITY MAP
PROVIDENCE
RHODE ISLAND
DATE
FEB. 1960
SCALE AS SHOWN
SPEC. NO.
DRAWING NUMBER
FP-1-1052
SHEET 1 OF 30

CORPS OF ENGINEERS

U. S. ARMY



Note:
Provide temporary sheet pile wall for canal bypass at West Abutment during construction of pumping station. Complete permanent wall when flow is diverted to pumping station passage.

PLAN

SCALE: 1" = 40'-0"

CONTROL POINTS FOR CANAL WALL BASE LINE

Point	N Coordinate	E Coordinate
W.P. #8	266716.86	526251.18
"Dust"	266834.94	526175.63
"West Bridge"	267521.79	525902.29
"End"	268277.43	525567.73

CONTROL POINTS FOR CANAL WALL

Point	N Coordinate	E Coordinate
W.P. #9	266798.923	526312.606
1	266808.105	526308.645
19	267973.384	526237.351
28	267044.625	526188.355
55	267282.147	526076.603
67	267399.320	526038.045
76	267488.827	526067.453
86	267585.530	526048.237
95	267664.624	526005.293
105	267725.951	525929.561
106	267728.791	525919.973
116A *	267732.520	525847.304
149	268103.125	525709.014

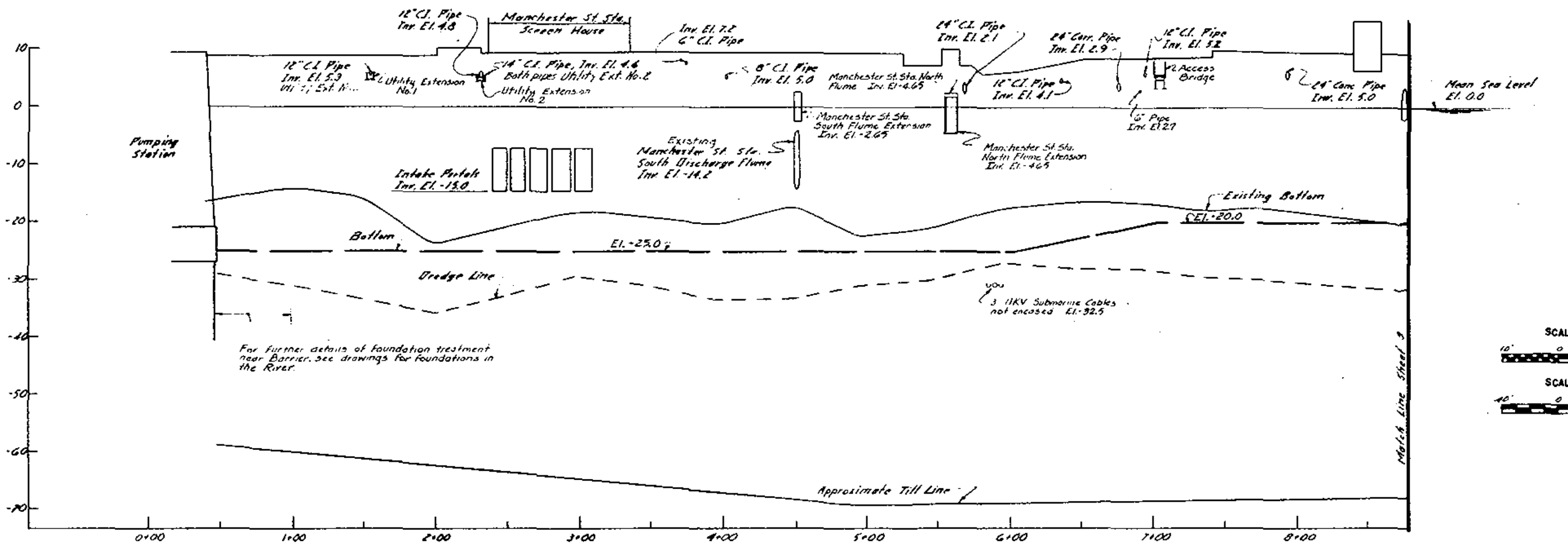
* 116A is the P.T. of curve 106-116A and no pile is driven there

CURVE DATA

Curve	Δ	L	R	T	No. Piles
55 - 67	30°-00'	120.0'	229.183'	61.409'	12
76 - 86	34°-30'	100.0'	166.074'	51.567'	10
95 - 105	45°-00'	100.0'	127.324'	52.739'	10
106 - 116A	48°-30'	100.0'	118.135'	53.216'	10

LEGEND

- ○ Pile Numbers
- ◇ Cooling Water Canal Section Numbers, see Sheets 12 thru 16.
- FD ● Foundation Test Boring Numbers, see Sheet 4.
- FP ● Foundation Test Probing Numbers, see Sheet 4.
- • Existing Piles
- Triangulation Point
- W.P. Working Point
- Cooling Water Canal Wall
- Armored Area



PROFILE

SCALE: HOR. 1" = 40'-0" VERT. 1" = 10'-0"

SCALE 1" = 10'-0"

SCALE 1" = 40'-0"

NOTES:

1. Profile is taken parallel to Base Line immediately inboard of the Cooling Water Canal Wall.
2. For details of Utility Extension No. 1, see Sh. 27.
3. For details of Utility Extension No. 2, see Sh. 28.
4. For details of Manchester St. Sta. - South Discharge Flume Extension, see Sh. 18.
5. For details of Manchester St. Sta. - North Discharge Flume Extension, see Sh. 21.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: C.R.D.
TRACED BY: C.R.D.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL

PLAN & PROFILE NO. 1

PROVIDENCE RHODE ISLAND

APPROVED

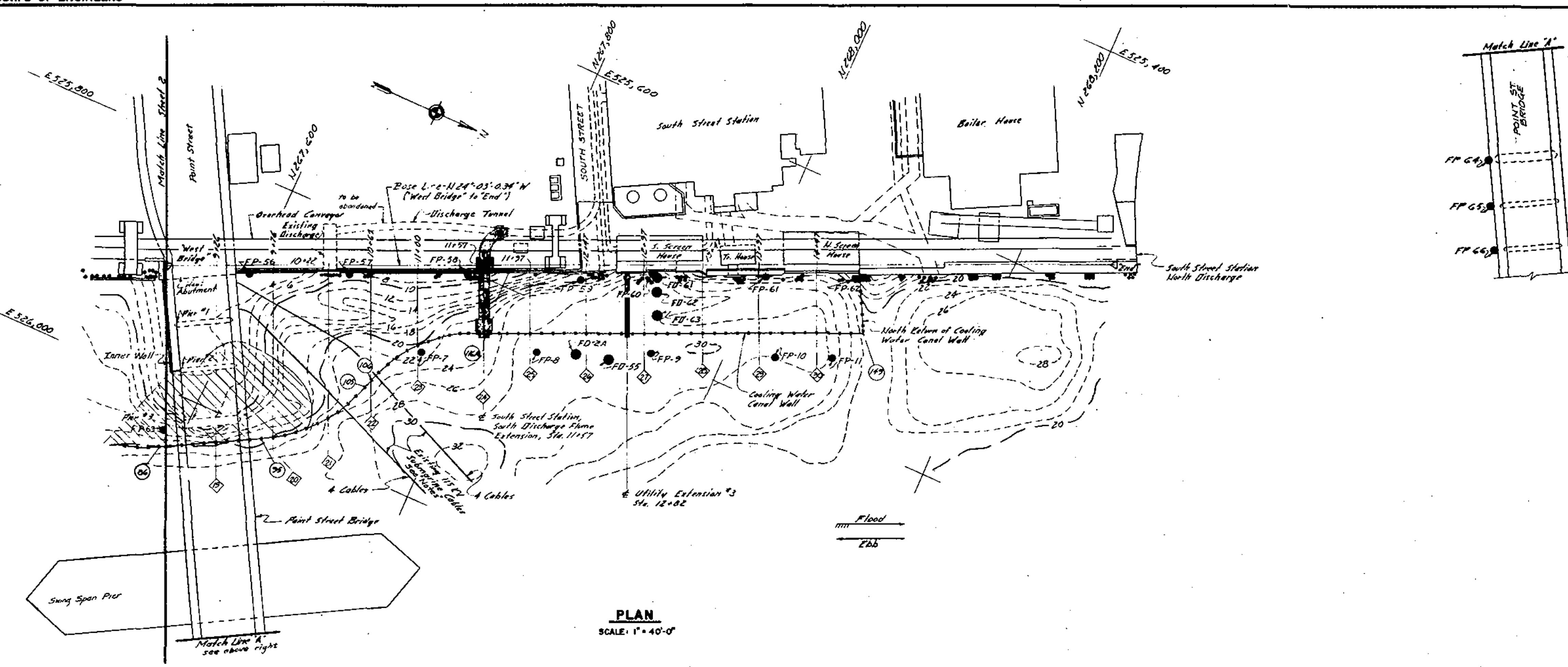
DATE FEB. 1960

SCALE AS SHOWN | SPEC. NO.

DRAWING NUMBER FP-1-1053

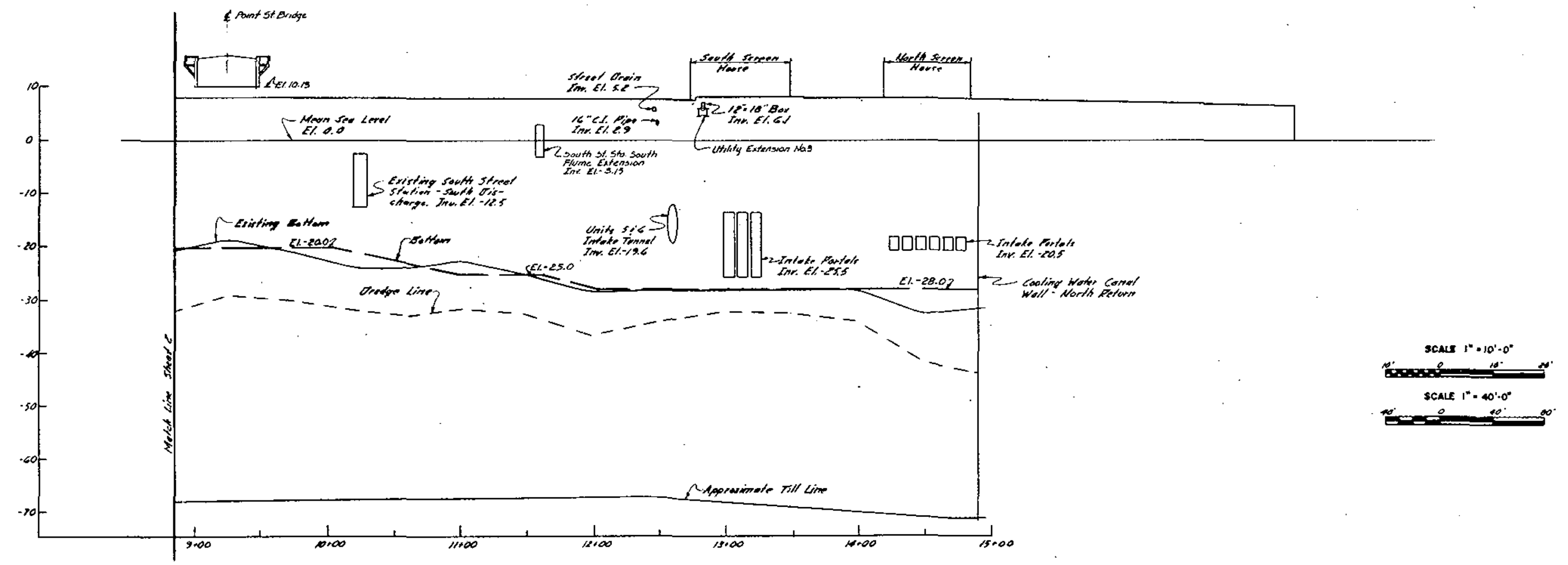
SHEET 2 OF 30

PLATE NO. 11-2



PLAN

SCALE: 1" = 40'-0"



PROFILE

SCALE: HOR. 1" = 40'-0"
VERT. 1" = 10'-0"

SCALE 1" = 10'-0"

SCALE 1" = 40'-0"

NOTES:

1. Profile is taken parallel to Base Line immediately inboard of the Cooling Water Canal Wall.
2. For "Legend", see Sh. 2.
3. For details of South Street Station - South Discharge Flume Extension, see Sh. 24.
4. For details of Utility Extension No. 3, see Sh. 29.
5. For alternate methods of wall construction in vicinity of 115 KV. live voltage submarine cables. See Sheet 7.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
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PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: C.R.D.
TRACED BY: C.R.D.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED
CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL
PLAN & PROFILE NO. 2

PROVIDENCE RHODE ISLAND

APPROVED
COL. C.E. DIST. DIVISION ENGINEER

DATE FEB. 1960

SCALE AS SHOWN
SPEC. NO.

DRAWING NUMBER FP-1-1054

SHEET 3 OF 30

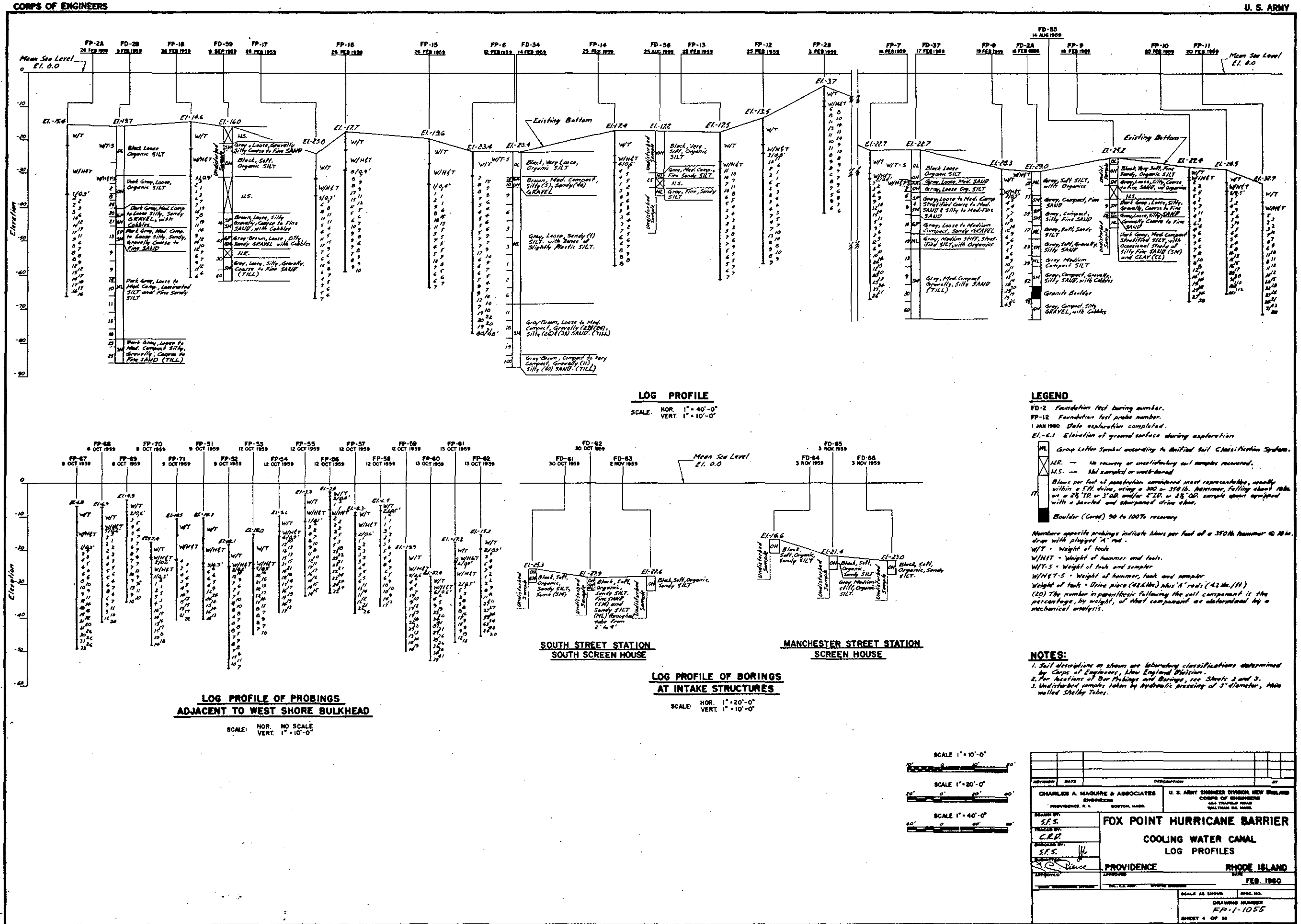
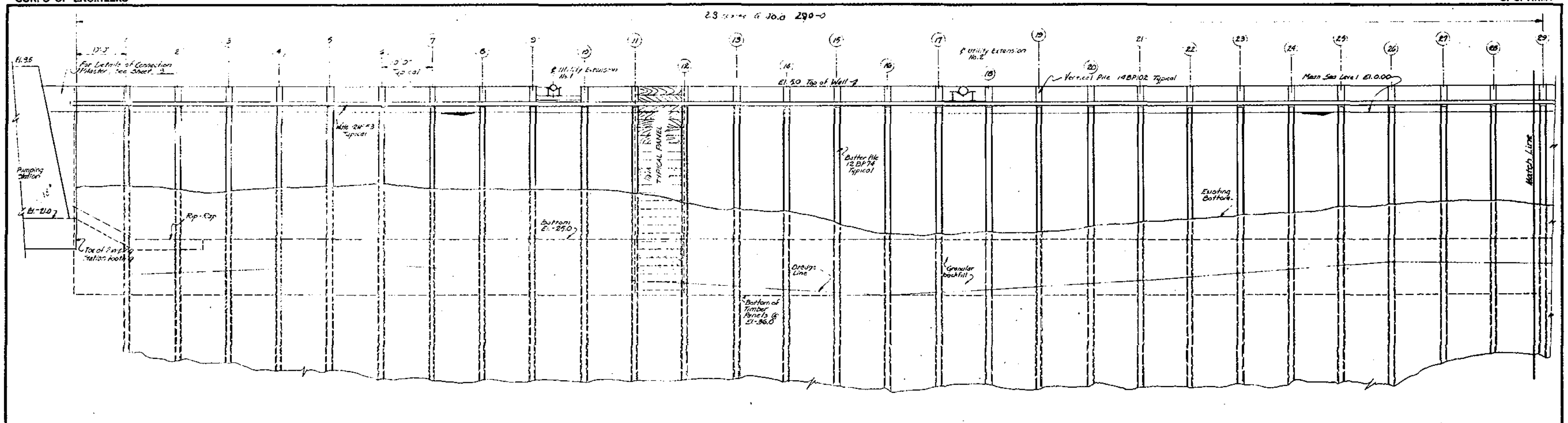
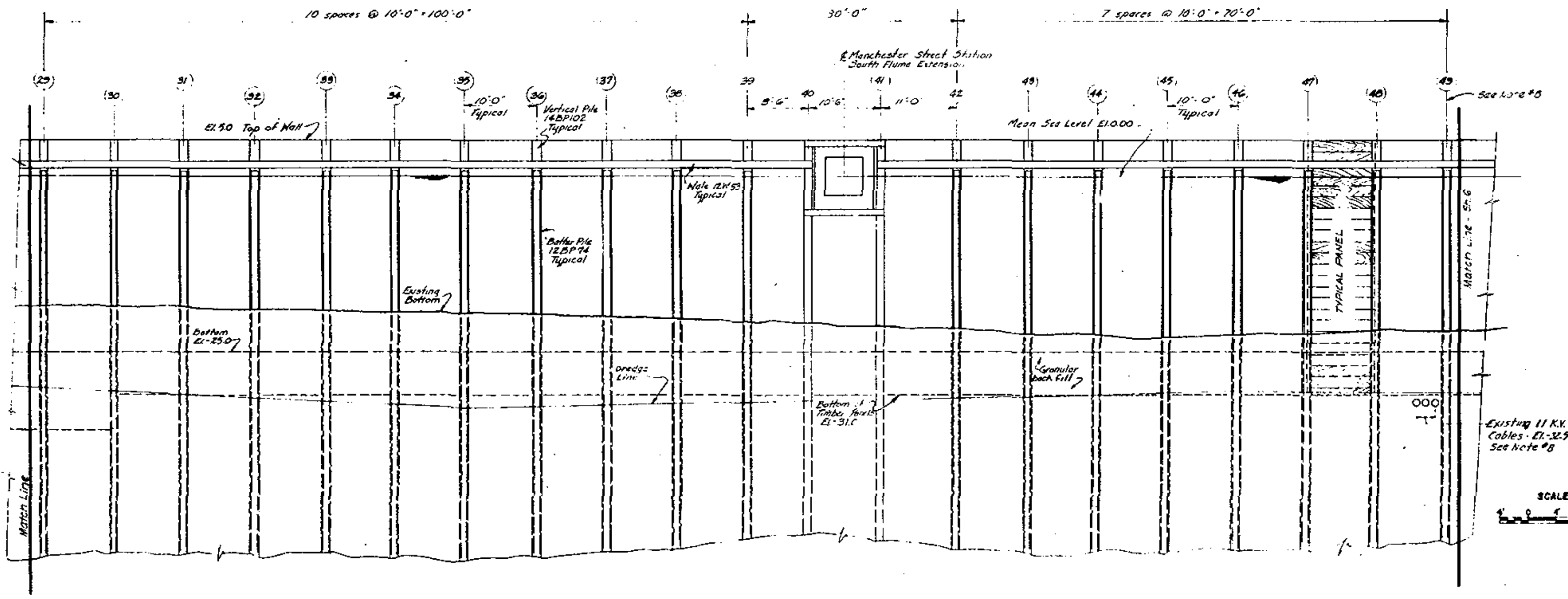

Mean Sea Level
El. 0.0
Elevation
Existing Bottom
LOG PROFILE
SCALE: HOR. 1" = 40'-0" VERT. 1" = 10'-0"
LOG PROFILE OF PROBINGS
ADJACENT TO WEST SHORE BULKHEAD
SCALE: HOR. NO SCALE VERT. 1" = 10'-0"
SOUTH STREET STATION
SOUTH SCREEN HOUSE
MANCHESTER STREET STATION
SCREEN HOUSE
LOG PROFILE OF BORINGS
AT INTAKE STRUCTURES
SCALE: HOR. 1" = 20'-0" VERT. 1" = 10'-0"
LEGEND
FD-2 Foundation test boring number.
FP-12 Foundation test probe number.
1 JAN 1960 Date exploration completed.
El.-6.1 Elevation of ground surface during exploration
ML Group Letter Symbol according to Unified Soil Classification System.
N.R. — No recovery or unsatisfactory soil samples recovered.
N.S. — Not sampled or wash-bored
Blows per foot of penetration considered most representative, usually within a 5 ft. drive, using a 300 or 350 lb. hammer, falling about 18 in. on a 2⅜" I.D. or 3" O.D. and/or 2" I.D. or 2⅜" O.D. sample spoon equipped with a beveled and sharpened drive shoe.
Boulder (Cored) 90 to 100% recovery
Numbers opposite probings indicate blows per foot of a 350 lb. hammer @ 18 in. drop with plugged "A" rod.
W/T = Weight of tools
W/H&T = Weight of hammer and tools.
W/T-S = Weight of tools and sampler
W/H&T-S = Weight of hammer, tools and sampler
Weight of tools = Drive piece (42.6 lbs.) plus "A" rods (4.2 lbs./ft.)
(20) The number in parenthesis following the soil component is the percentage, by weight, of that component as determined by a mechanical analysis.
NOTES:
1. Soil descriptions as shown are laboratory classifications determined by Corps of Engineers, New England Division.
2. For locations of Bar Probings and Borings, see Sheets 2 and 3.
3. Undisturbed samples taken by hydraulic pressing of 3" diameter, thin walled Shelby Tubes.
SCALE 1" = 10'-0"
SCALE 1" = 20'-0"
SCALE 1" = 40'-0"
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.
DRAWN BY: S.F.S.
TRACED BY: C.R.D.
CHECKED BY: S.F.S.
FOX POINT HURRICANE BARRIER
COOLING WATER CANAL
LOG PROFILES
PROVIDENCE
RHODE ISLAND
FEB. 1960
SCALE AS SHOWN
SPEC. NO.
DRAWING NUMBER
FP-1-1055
SHEET 4 OF 30

PLATE NO. II-4



ELEVATION



ELEVATION

NOTES:

1. Elevations shown on this sheet are "developed" elevations; for Plan of the Cooling Water Canal Wall, see Sh. 2.
2. For typical sections and details of Cooling Water Canal Wall, see Sh. 8 & Sh. 9.
3. For details of Manchester St. Sta. - South Discharge Flume Extension, see Sh. 18.
4. H-piles #40 and #41 are driven in conjunction with construction of the discharge flume extension.
5. H-pile #39 is driven after construction of the discharge flume extension.
6. For details of Utility Extension No. 1, see Sh. 27.
7. For details of Utility Extension No. 2, see Sh. 28.
8. The location of vertical H-pile #49 and the 3 - 11KV submarine cables appear, on the basis of available drawings to conflict. Two alternate solutions are as follows:
   a) the exact location of the submarine cables shall be determined by the contractor and H-pile #49 driven if possible. If necessary, eliminate H-pile #49 and increase the section of adjacent H-piles #48 and #50 to 14BP117 from the typical 14BP102.
9. All battered and vertical piles are to be driven to refusal into till stratum.

SCALE 1/8" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.E.
TRACED BY: A.E.
CHECKED BY: G.E.A.
SUBMITTED:
APPROVED

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL WALL
ELEVATION NO.1

PROVIDENCE RHODE ISLAND

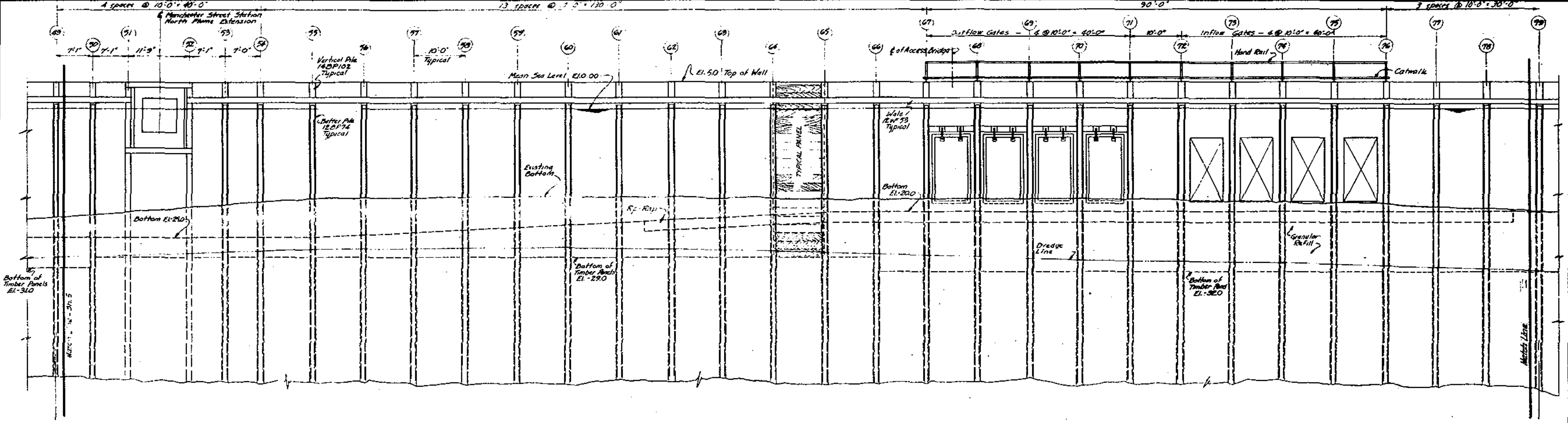
APPROVED
DATE FEB. 1960

SCALE 1/8" = 1'-0" SPEC. NO.

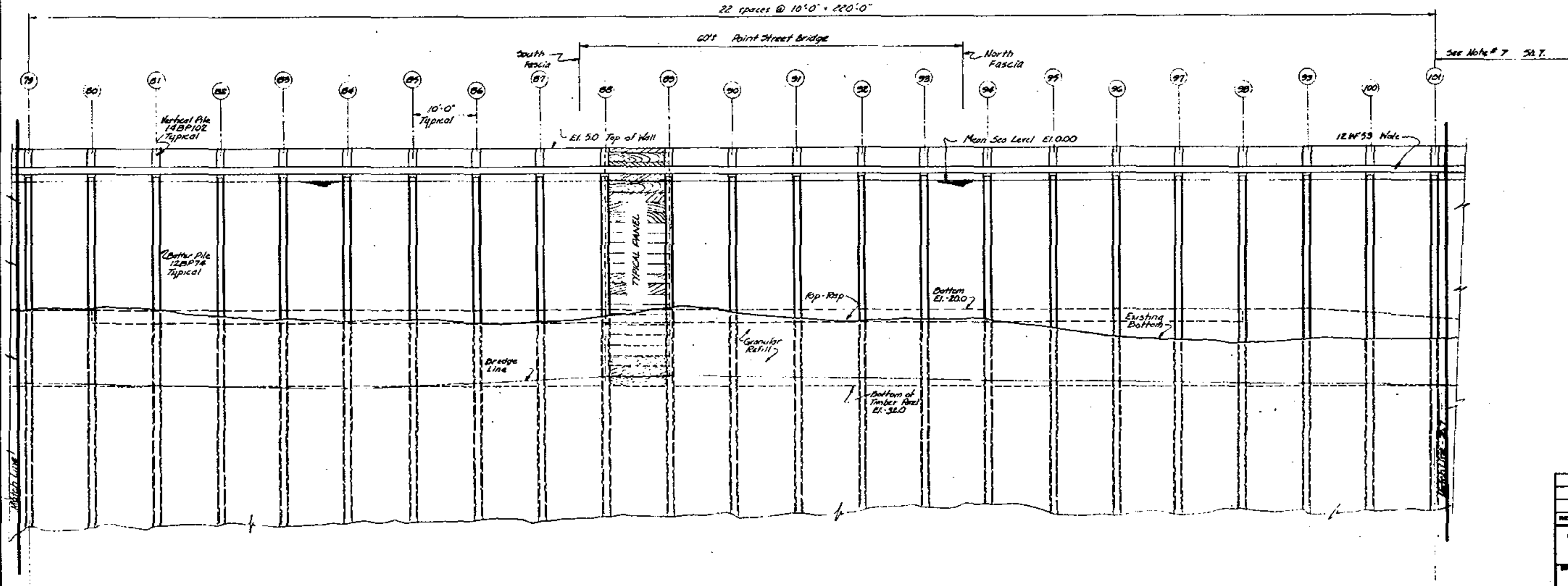
DRAWING NUMBER FP-1-1056

SHEET 5 OF 30

CORPS OF ENGINEERS U. S. ARMY



ELEVATION



ELEVATION

SCALE 1/8" = 1'-0"

NOTES:

1. Elevations shown on this sheet are "developed" elevations; for Plan of the Cooling Water Canal Wall, see Sh. 2 & Sh. 5.
2. For typical sections and details of Cooling Water Canal Wall, see Sh. 8 & Sh. 9.
3. For details of Manchester St. Sta. - North Discharge Flume Extension, see Sh. 21.
4. H-piles #51 & #52 are driven in conjunction with construction of the discharge flume extension.
5. H-piles #50 & #53 are driven after construction of the discharge flume extension.
6. For details of the Flap Gates & Catwalk, see Sh. 10.
7. For details of the Access Bridge, see Sh. 11.
8. For sections thru Point St. Bridge, see Sh. 17.
9. All battered and vertical piles are to be driven to refusal into till stratum.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A. Z.
TRACED BY: A. Z.
CHECKED BY: G. L. A.
SUBMITTED: A. S. Pierce
APPROVED

FOX POINT HURRICANE BARRIER

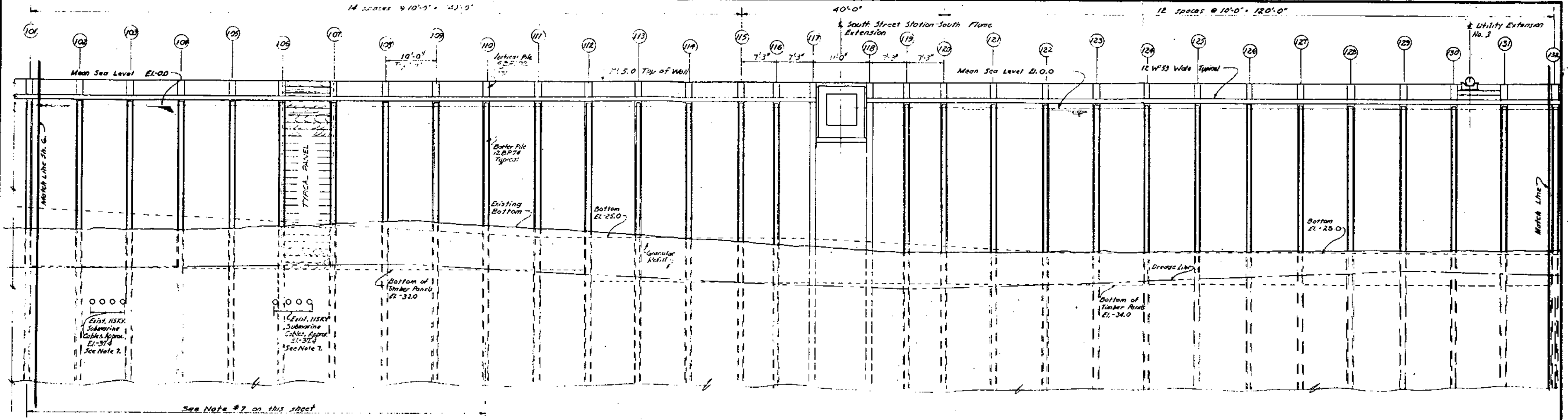
COOLING WATER CANAL WALL
ELEVATION NO. 2

PROVIDENCE RHODE ISLAND

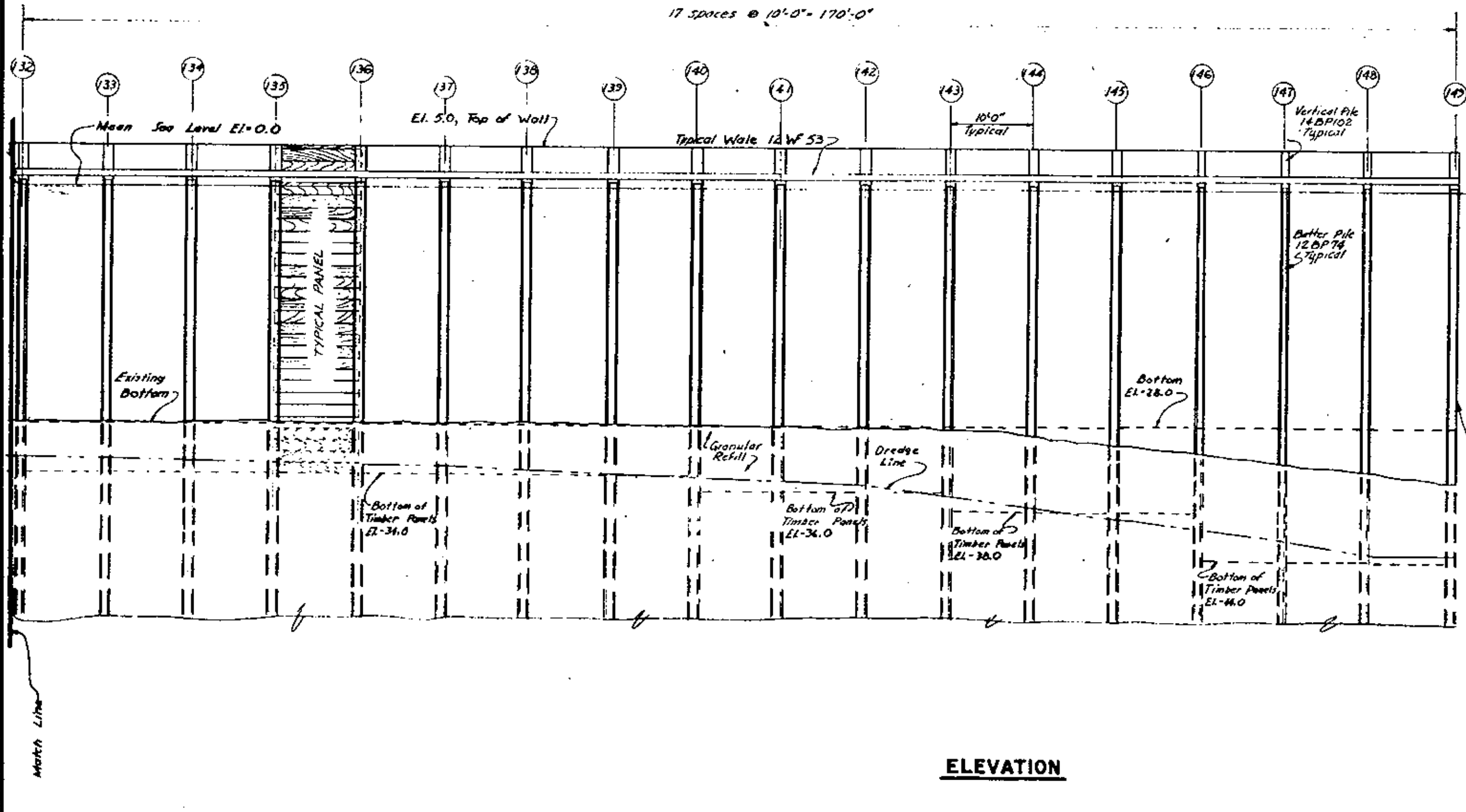
APPROVED
DATE FEB. 1960

SCALE 1/8" = 1'-0"
SPEC. NO.
DRAWING NUMBER FP-1-1057
SHEET 6 OF 36

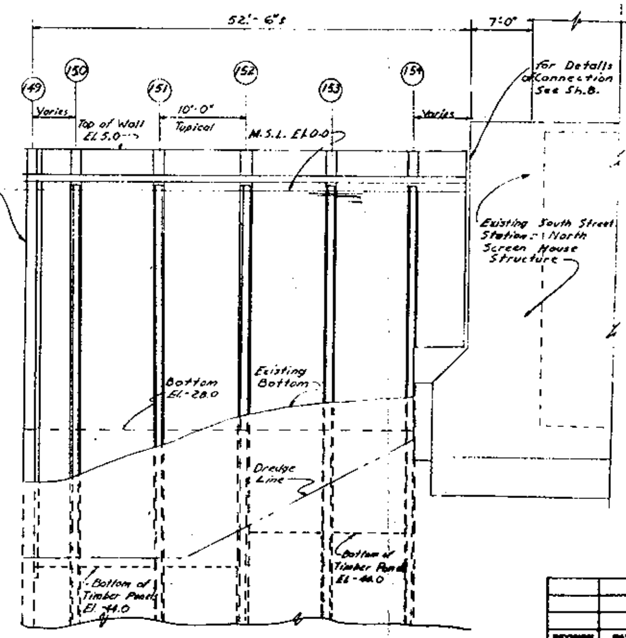
PLATE NO. 11-6



ELEVATION



ELEVATION



ELEVATION OF NORTH RETURN

SCALE 1/8" = 1'-0"

4 0 4 8 12 16' 20'

NOTES:

1. Elevations shown on this sheet are "developed" elevations; for Plan of Cooling Water Canal, see Sh. 2.
2. For typical sections and details of Cooling Water Canal Wall, see Sh. 8 and Sh. 9.
3. For details of South Street Station-South Discharge Flume Extension, see Sh. 24.
4. H-piles #117 and #118 are driven in conjunction with construction of the discharge flume extension.
5. H-piles #116 and #119 are driven after construction of the discharge flume extension.
6. For details of Utility Extension No. 3, see Sh. 29.
7. Exact location by field diver survey of the existing live high voltage 115KV Submarine Cables may require altering the spacing of H-Piles #101 thru #110. For alternate methods of wall construction, see sheet 5. For information pertaining to these cables, see New England Power Service Company drawing NO. PH 5074-5.
8. All battered and vertical piles are to be driven to refusal into the system.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.R.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
SUBMITTED: [signature]
APPROVED:

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL WALL
ELEVATION NO.3

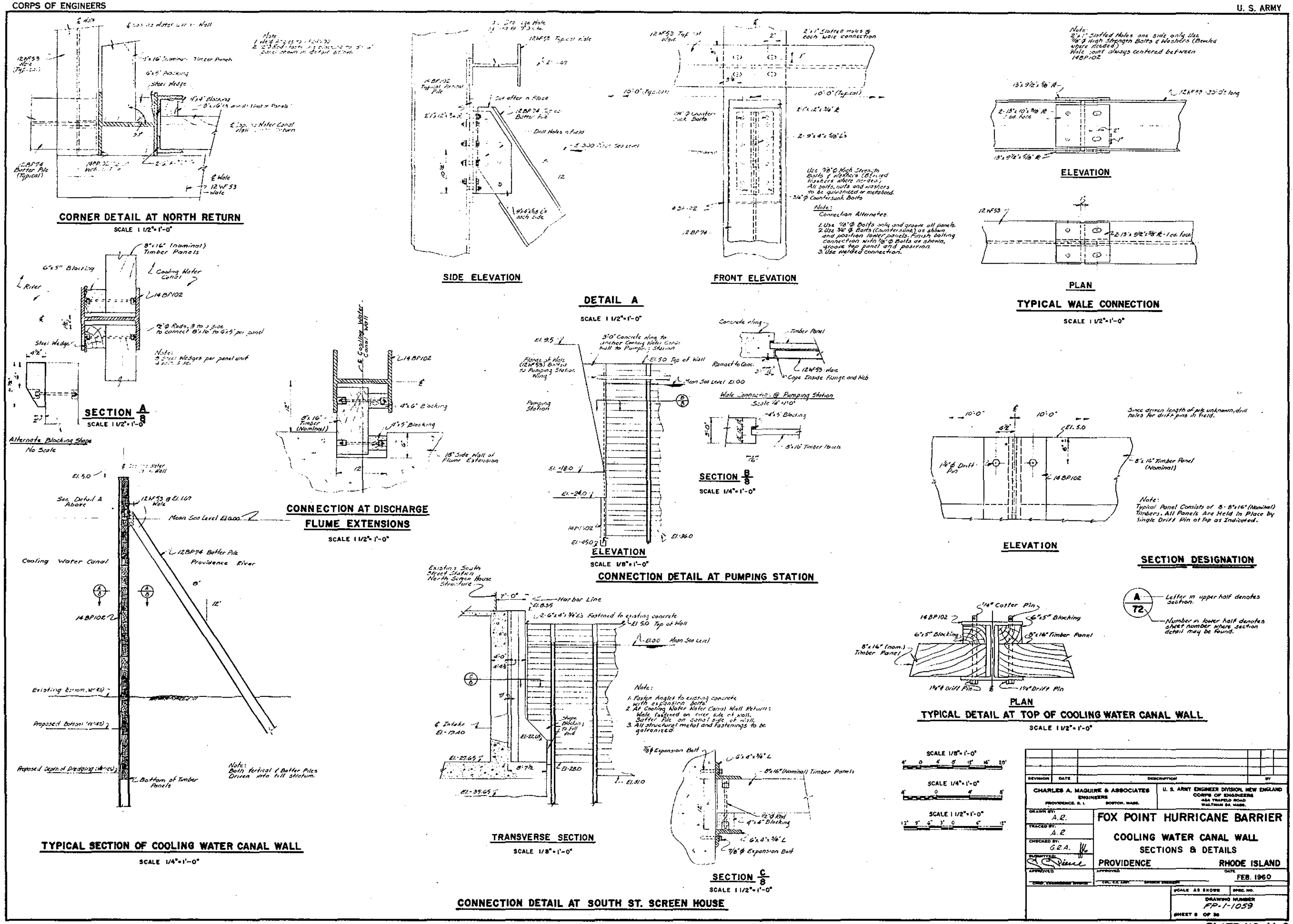
PROVIDENCE RHODE ISLAND

DATE: FEB. 1960

SCALE 1/8" = 1'-0" SPEC. NO.

DRAWING NUMBER FP-1-1058

SHEET 7 OF 34


CORNER DETAIL AT NORTH RETURN
SCALE 1 1/2"=1'-0"
SIDE ELEVATION
FRONT ELEVATION
DETAIL A
SCALE 1 1/2"=1'-0"
ELEVATION
PLAN
TYPICAL WALE CONNECTION
SCALE 1 1/2"=1'-0"
SECTION A/8
SCALE 1 1/2"=1'-0"
Alternate Blocking Shape
No Scale
CONNECTION AT DISCHARGE FLUME EXTENSIONS
SCALE 1 1/2"=1'-0"
ELEVATION
SCALE 1/8"=1'-0"
CONNECTION DETAIL AT PUMPING STATION
SECTION B/8
SCALE 1/4"=1'-0"
ELEVATION
SECTION DESIGNATION
Letter in upper half denotes section.
Number in lower half denotes sheet number where section detail may be found.
Note: Typical Panel Consists of 8-8"x16" (Nominal) Timbers. All Panels Are Held in Place by Single Drift Pin at Top as Indicated.
PLAN
TYPICAL DETAIL AT TOP OF COOLING WATER CANAL WALL
SCALE 1 1/2"=1'-0"
TYPICAL SECTION OF COOLING WATER CANAL WALL
SCALE 1/4"=1'-0"
Note: Both Vertical & Batter Piles Driven into till stratum.
Mean Sea Level El.0.00
Cooling Water Canal
Providence River
TRANSVERSE SECTION
SCALE 1/8"=1'-0"
SECTION C/8
SCALE 1 1/2"=1'-0"
CONNECTION DETAIL AT SOUTH ST. SCREEN HOUSE
Note:
1. Fasten Angles to existing concrete with expansion bolts.
2. At Cooling Water Canal Wall Return: Wale fastened on river side of wall. Batter Pile on canal side of wall.
3. All structural metal and fastenings to be galvanized.
SCALE 1/8"=1'-0"
SCALE 1/4"=1'-0"
SCALE 1 1/2"=1'-0"
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I.
BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM 54, MASS.
DRAWN BY: A.R.
TRACED BY: A.R.
CHECKED BY: G.Z.A.
FOX POINT HURRICANE BARRIER
COOLING WATER CANAL WALL
SECTIONS & DETAILS
PROVIDENCE
RHODE ISLAND
FEB. 1960
SCALE AS SHOWN
DRAWING NUMBER
FP-1-1059

CORPS OF ENGINEERS

U. S. ARMY

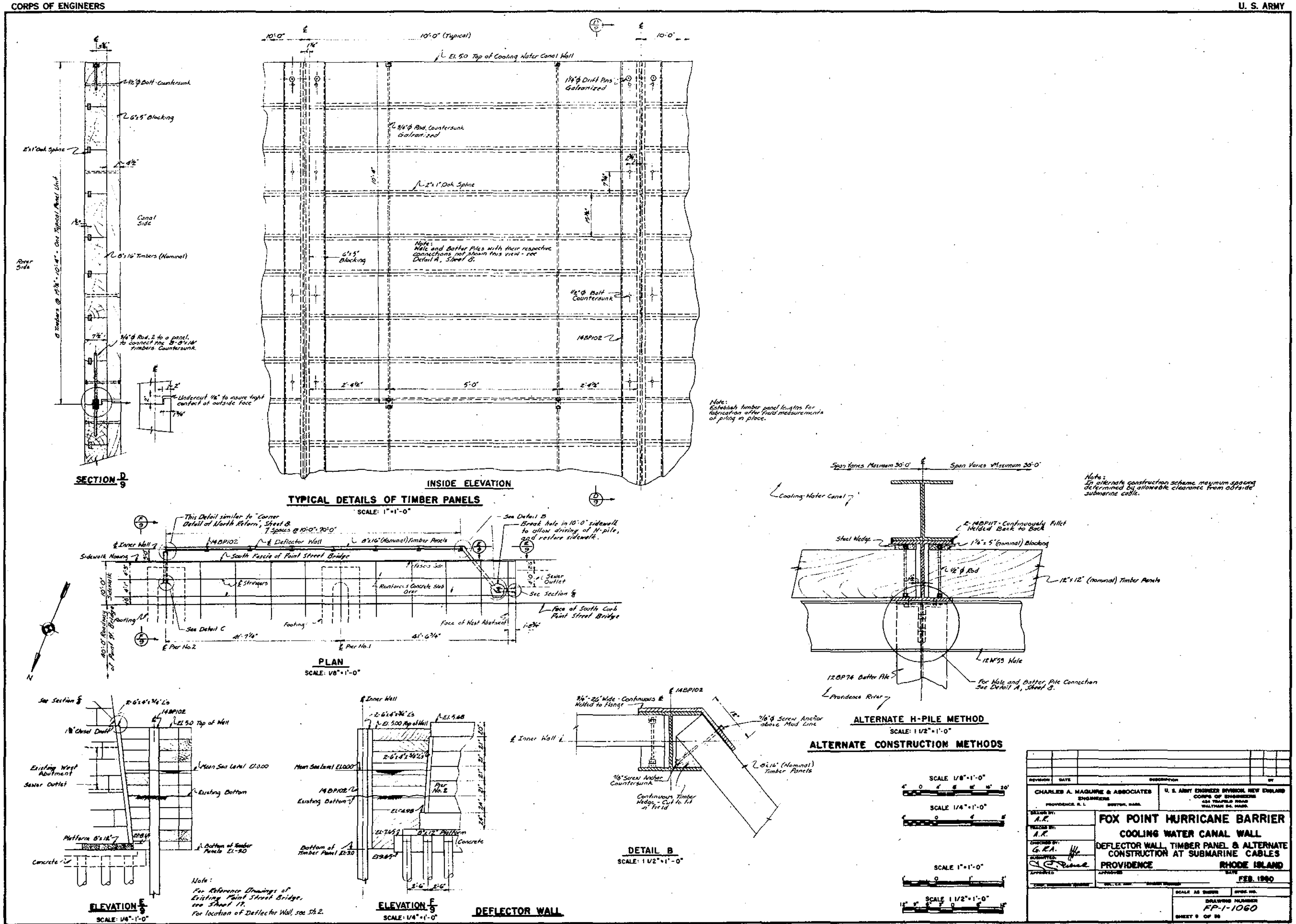
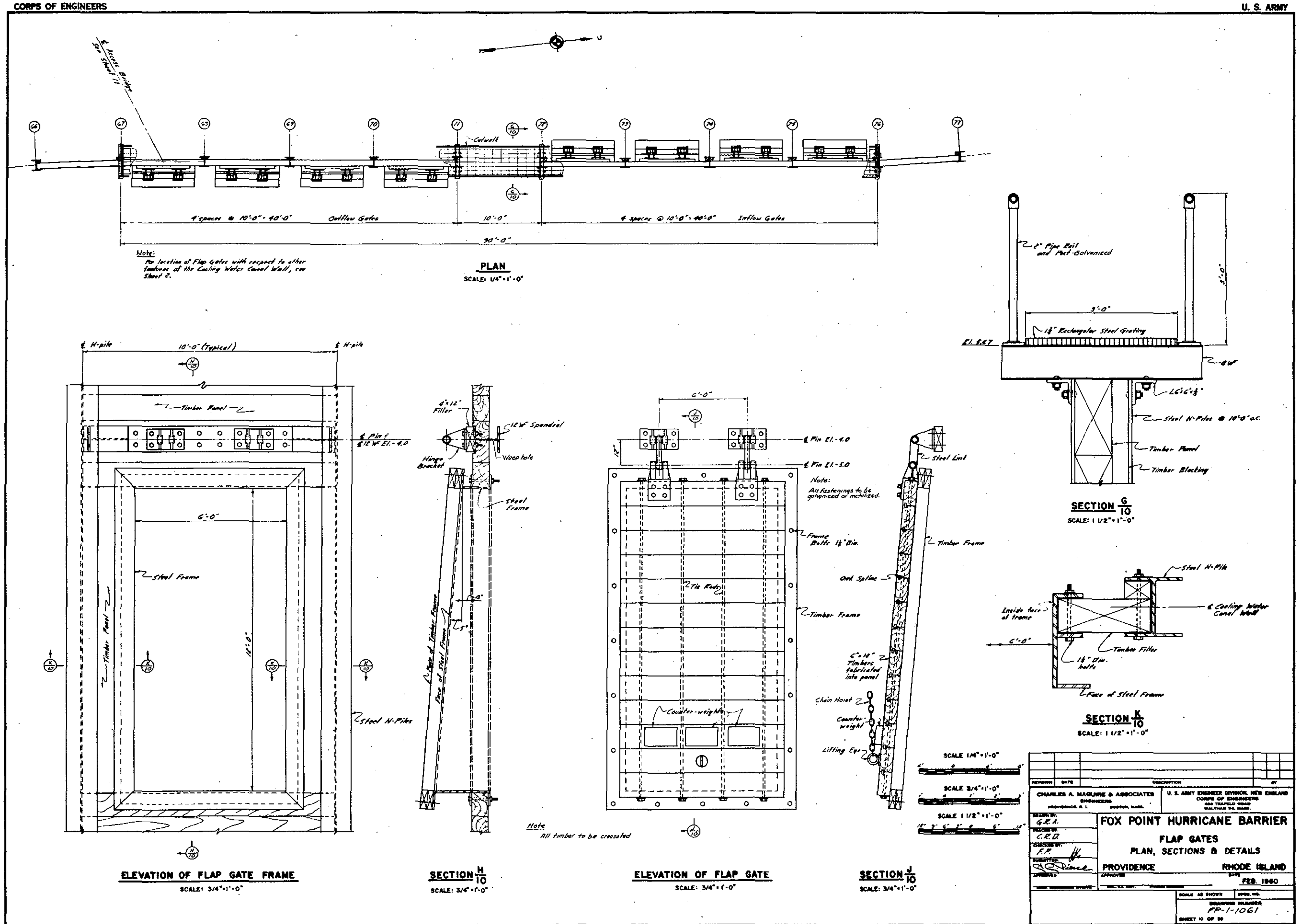


PLATE NO. 11-9


PLAN
SCALE: 1/4" = 1'-0"
Note:
For location of Flap Gates with respect to other features of the Cooling Water Canal Wall, see Sheet 2.
4 spaces @ 10'-0" = 40'-0" Outflow Gates
10'-0"
4 spaces @ 10'-0" = 40'-0" Inflow Gates
90'-0"
Catwalk
ELEVATION OF FLAP GATE FRAME
SCALE: 3/4" = 1'-0"
10'-0" (Typical)
Timber Panel
Steel Frame
Steel H-Piles
6'-0"
12'-0"
SECTION H/10
SCALE: 3/4" = 1'-0"
Hinge Bracket
Weep hole
Steel Frame
Note
All timber to be creosoted
ELEVATION OF FLAP GATE
SCALE: 3/4" = 1'-0"
6'-0"
Note:
All fastenings to be galvanized or metalized.
Tie Rods
Timber Frame
Counter-weights
SECTION J/10
SCALE: 3/4" = 1'-0"
Steel Link
Timber Frame
Oak Spline
Chain Hoist
Counter-weight
Lifting Eye
2" Pipe Rail and Post Galvanized
1½" Rectangular Steel Grating
3'-0"
Steel H-Piles @ 10'-0" o.c.
Timber Panel
Timber Blocking
SECTION G/10
SCALE: 1 1/2" = 1'-0"
Steel H-Pile
Inside face of frame
Timber Filler
Face of Steel Frame
SECTION K/10
SCALE: 1 1/2" = 1'-0"
SCALE 1/4" = 1'-0"
SCALE 3/4" = 1'-0"
SCALE 1 1/2" = 1'-0"
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM 54, MASS.
G.K.A.
C.R.D.
F.P.
FOX POINT HURRICANE BARRIER
FLAP GATES
PLAN, SECTIONS & DETAILS
PROVIDENCE
RHODE ISLAND
FEB. 1960
SCALE AS SHOWN
FP-1-1061

CORPS OF ENGINEERS U. S. ARMY

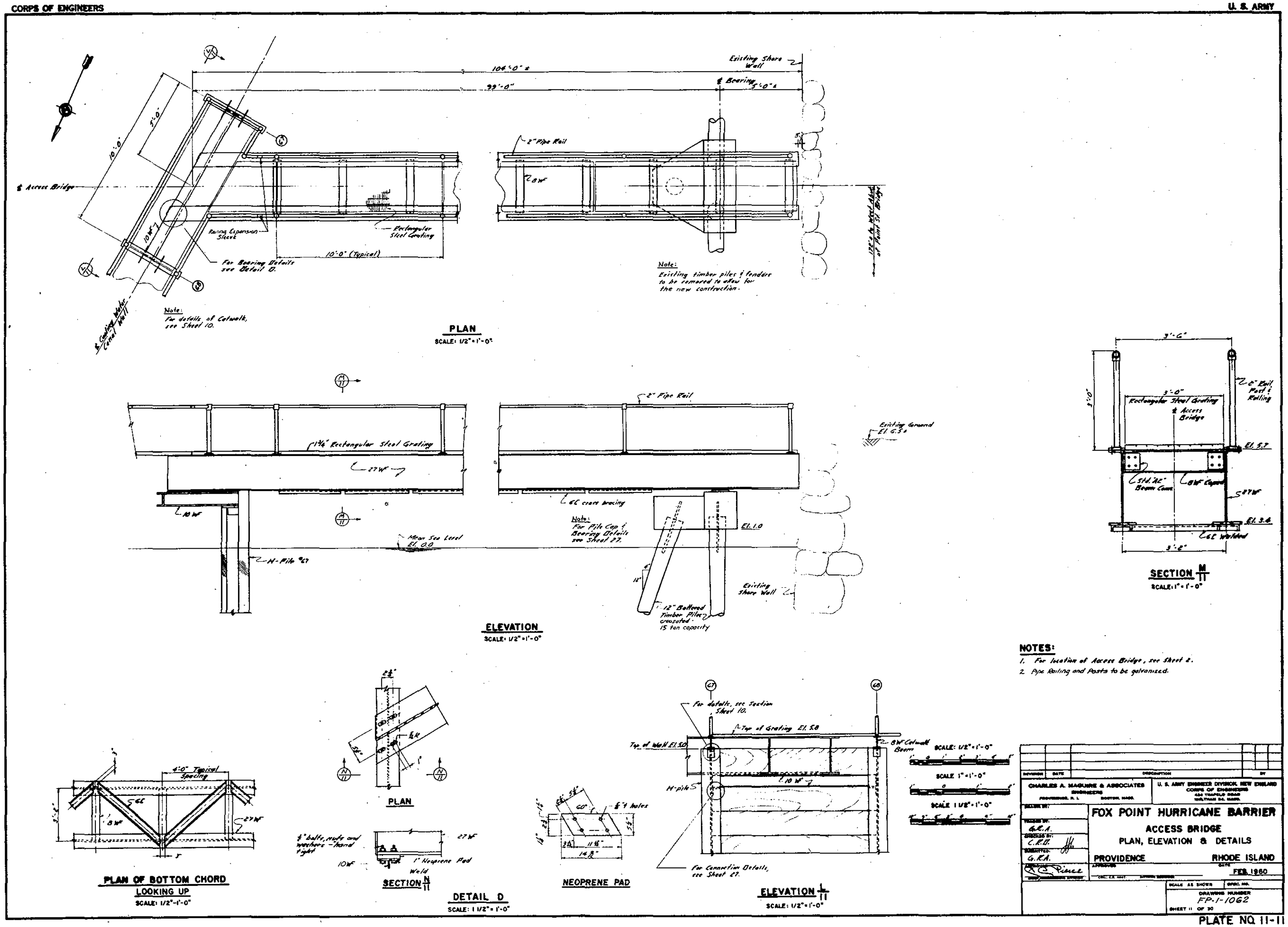
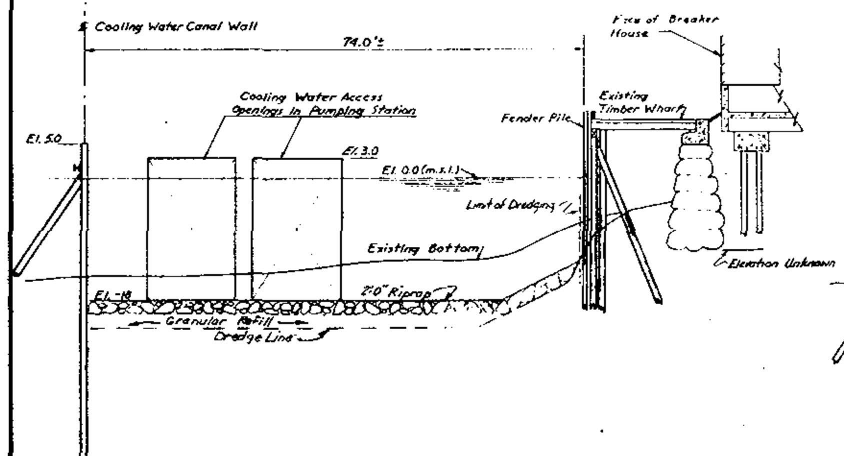
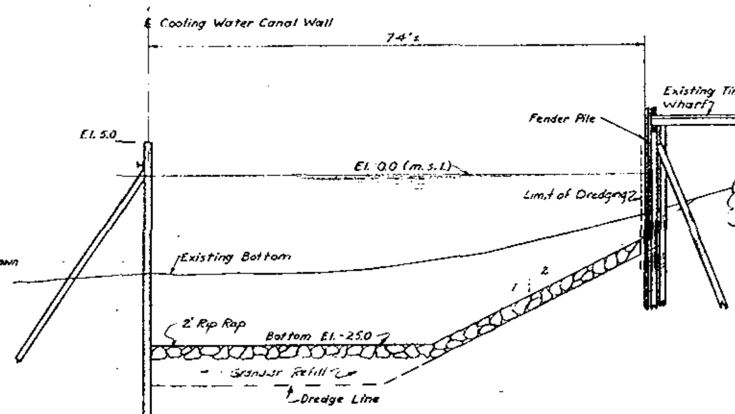


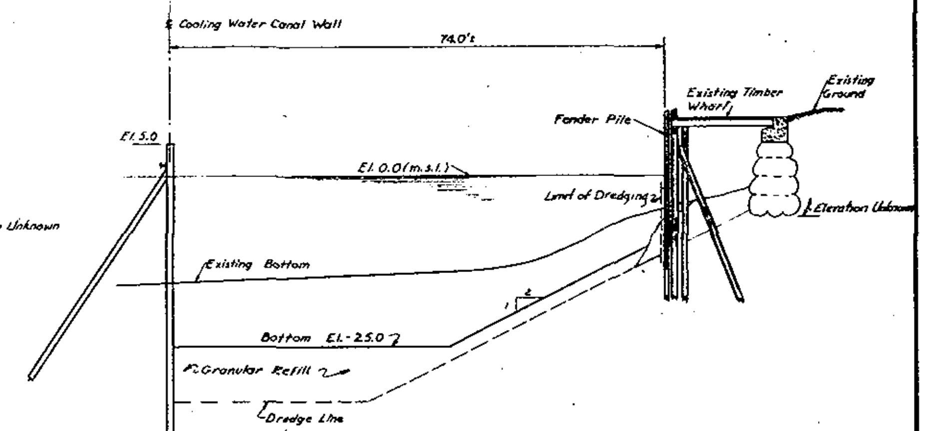
PLATE NO. 11-11



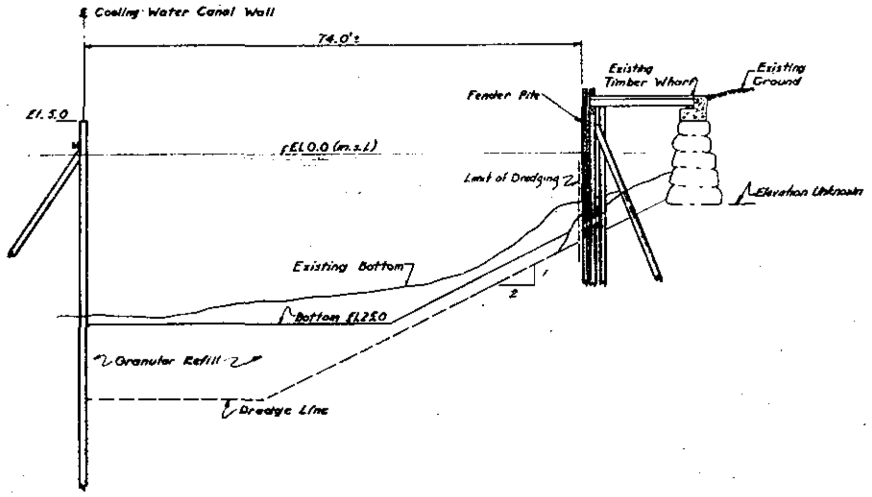
SECTION 1 AT STA. 0+52



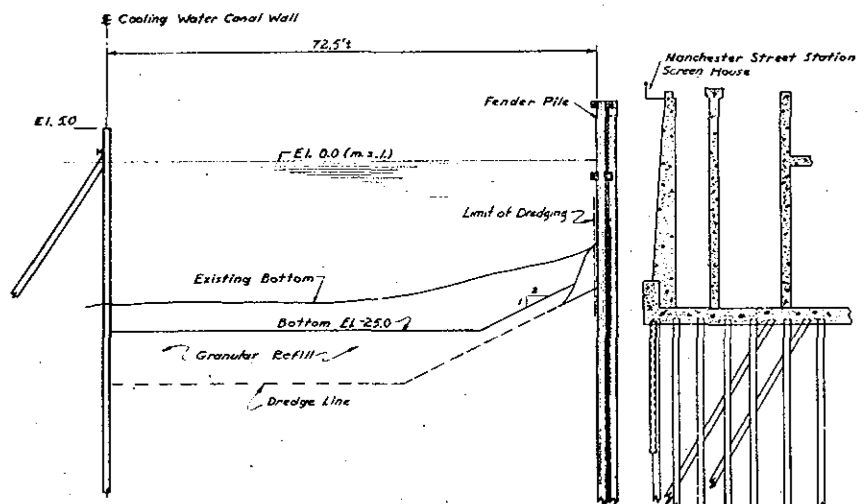
SECTION 2 AT STA. 1+02



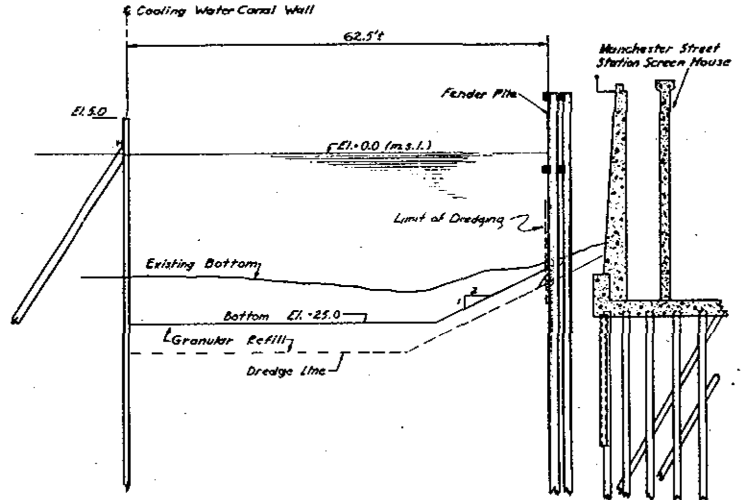
SECTION 3 AT STA. 1+52



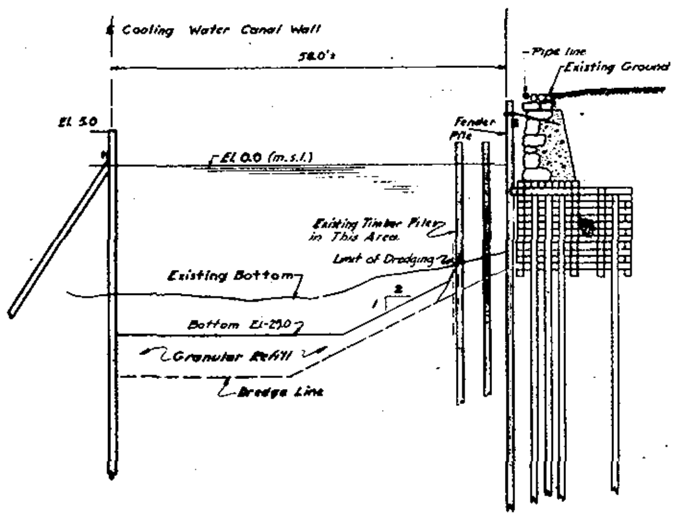
SECTION 4 AT STA. 2+02



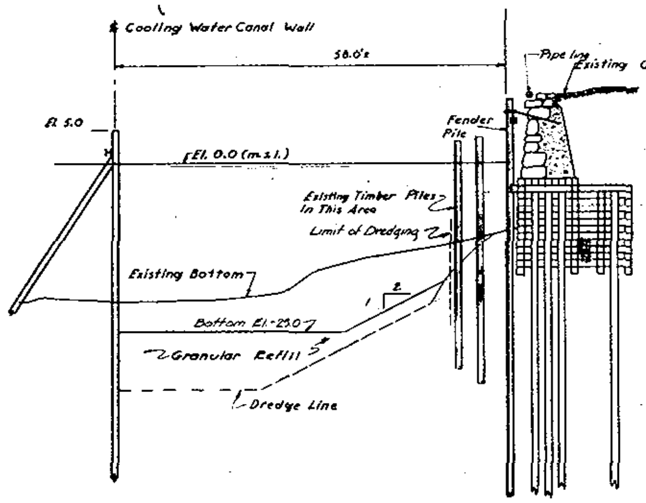
SECTION 5 AT STA. 2+51



SECTION 6 AT STA. 3+00



SECTION 7 AT STA. 3+48



SECTION 8 AT STA. 3+98

NOTES:

1. Existing Shore Bulkheads and Structures are Based on New England Power Service Company Drawings Numbers: B-2030, H-7861-0.
2. For location of sections, see sheet no. 2.
3. Existing River Bottom within Cooling Water Canal, taken from Soundings and Probings, shown on sheets 2 & 3.
4. Contractor shall locate the bottom of the existing bulkhead wall prior to commencement of dredging adjacent to the bulkhead. Based on limited available probing data, the 2 on 1 sloped dredge line has been established so that its extension will not intersect below the base of any existing wall construction. The sloped dredge line shall be adjusted as necessary to suit field conditions.

SCALE 1" = 10'-0"

10' 0 10 20'

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.R.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
SUBMITTED: [signature]
APPROVED

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL

SECTIONS 1 THRU 8

PROVIDENCE RHODE ISLAND

APPROVED

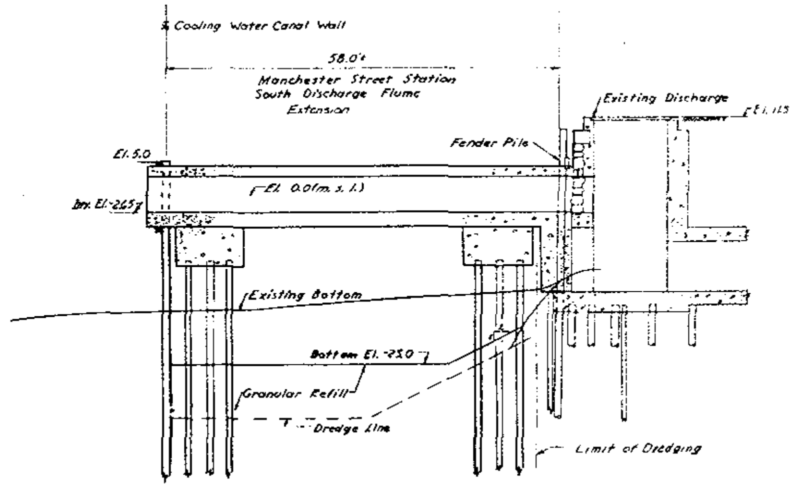
DATE FEB. 1960

SCALE 1" = 10'-0"

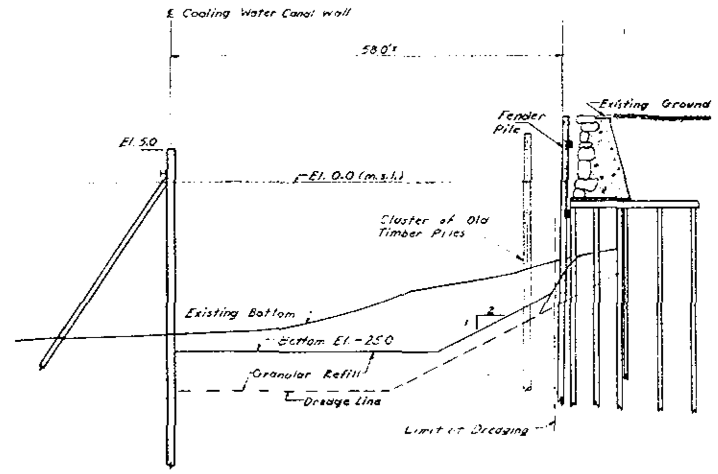
SPEC. NO.

DRAWING NUMBER FP-1-1063

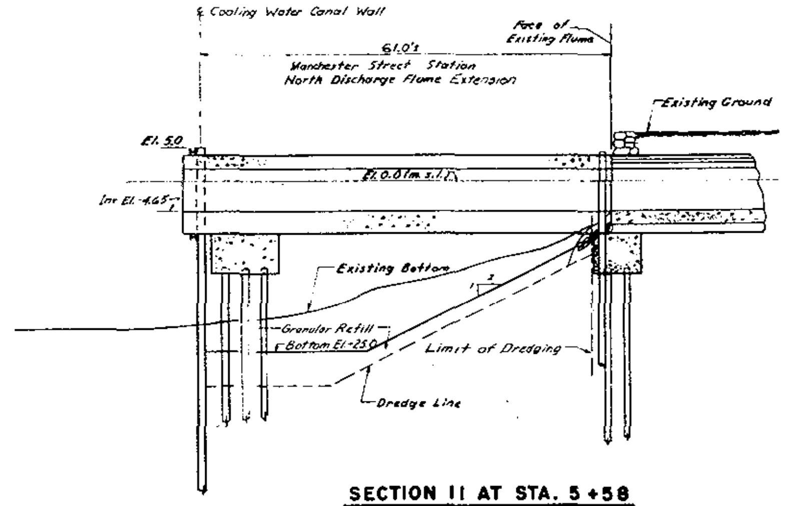
SHEET 12 OF 30



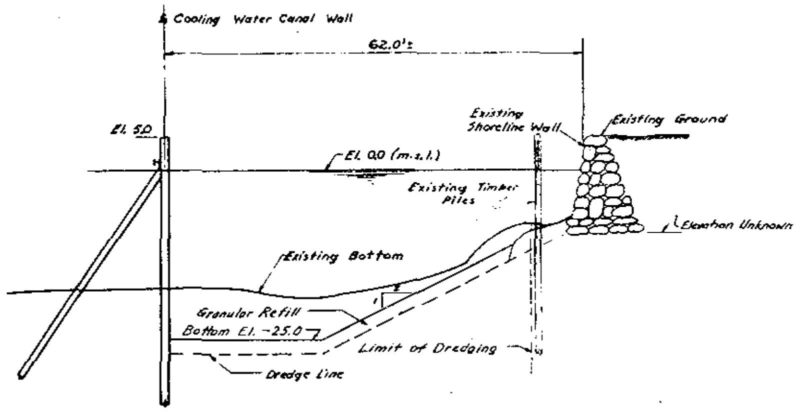
SECTION 9 AT STA. 4+53



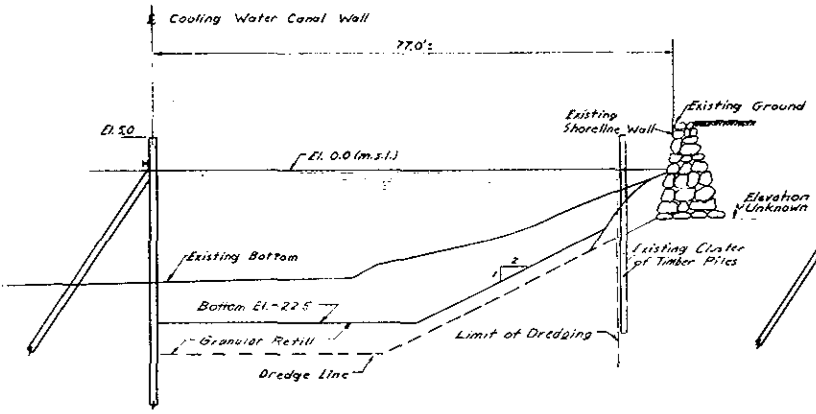
SECTION 10 AT STA. 4+98



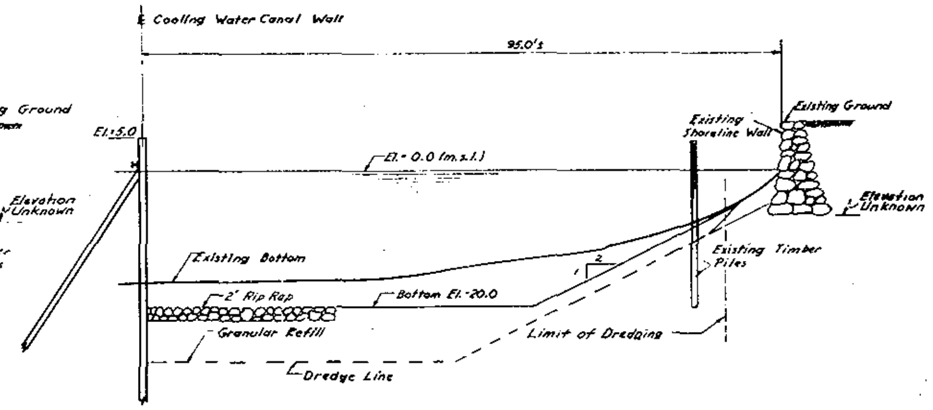
SECTION 11 AT STA. 5+58



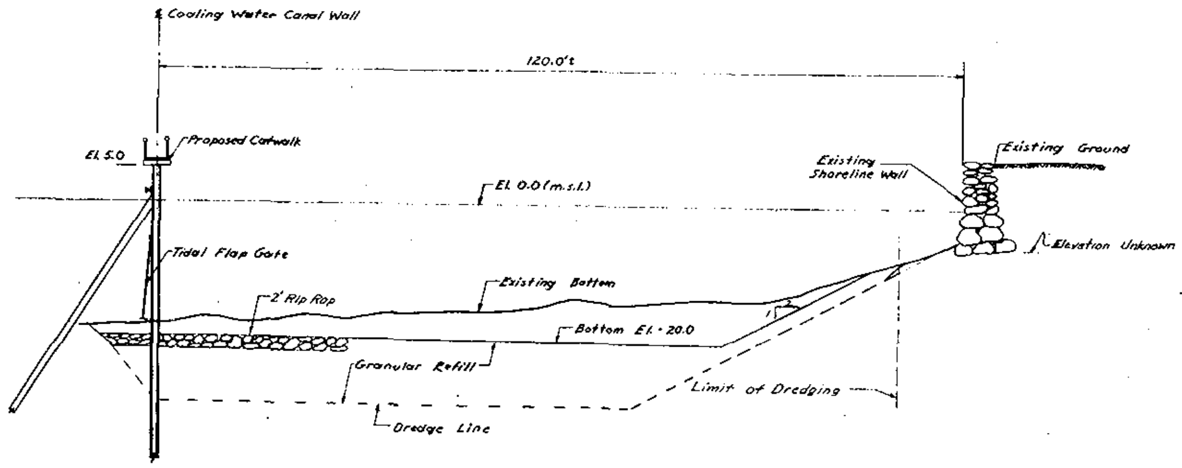
SECTION 12 AT STA. 5+98



SECTION 13 AT STA. 6+48



SECTION 14 AT STA. 6+95



SECTION 15 AT STA. 7+38

NOTES:

1. Existing Shore Bulkheads and Structures are Based on New England Power Service Company Drawings Numbers: 8673-812, H-7841-O, A-8125-G.
2. For location of sections, See Sheet No. 2.
3. Existing River Bottom within Cooling Water Canal taken from Soundings and Probings shown on Sheets 2 and 3.

SCALE 1" = 10'-0"

10' 0 10' 20'

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.K.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED:
CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL
SECTIONS 9 THRU 15

PROVIDENCE RHODE ISLAND

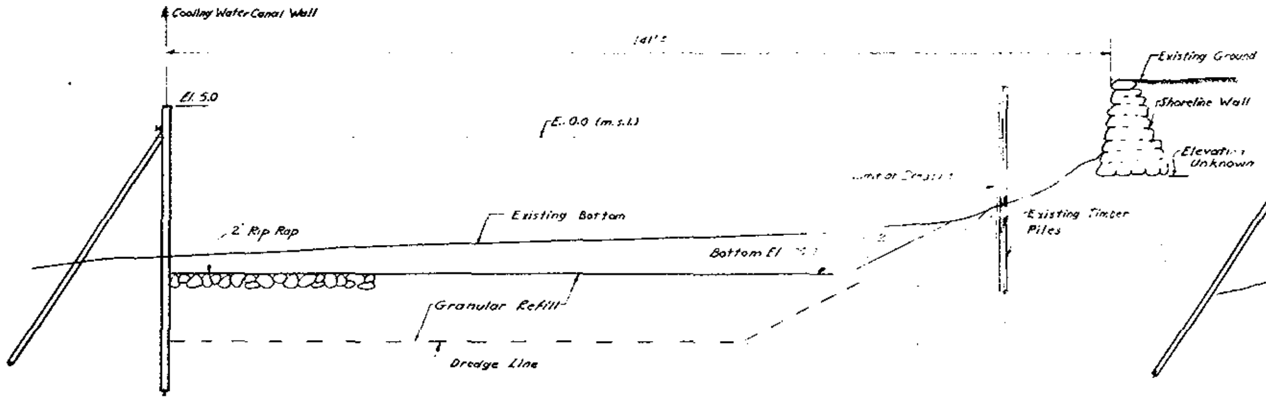
APPROVED: COL., C.E. ARMY DIVISION ENGINEER

DATE: FEB. 1960

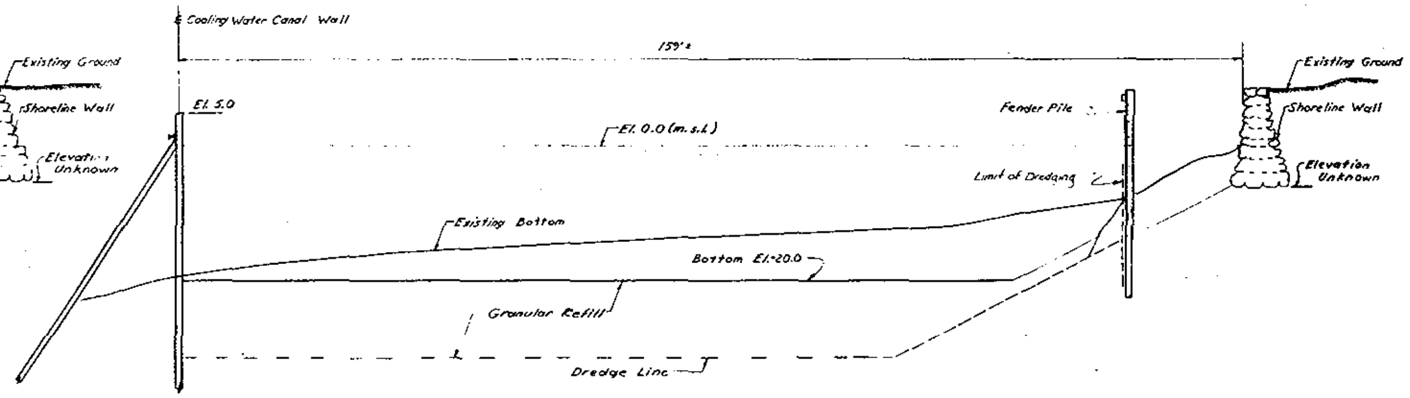
SCALE 1" = 10'-0" SPEC. NO.

DRAWING NUMBER FP-1-1064

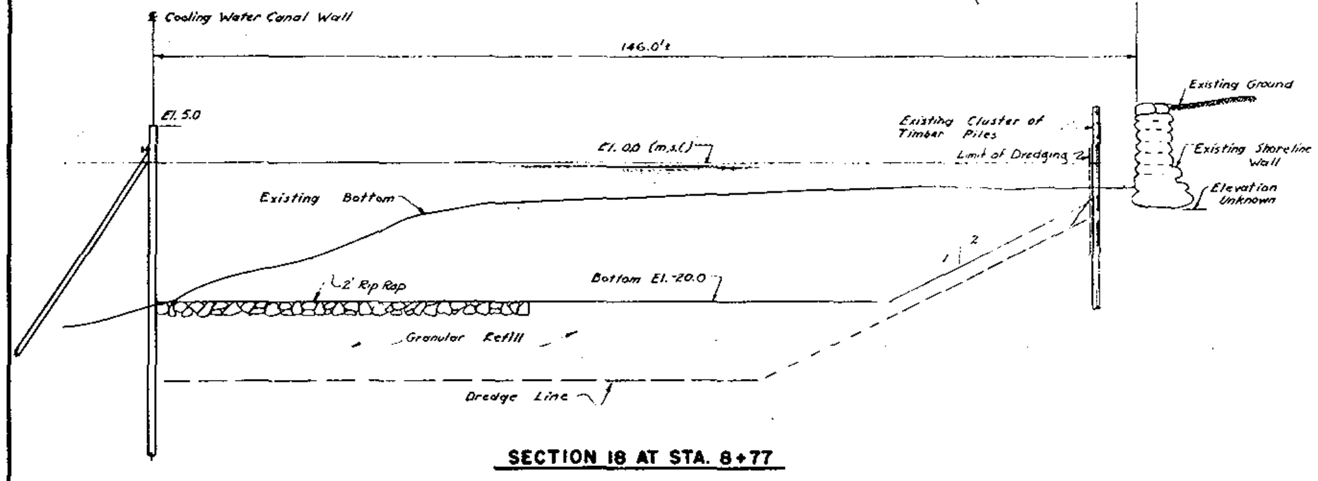
SHEET 13 OF 30



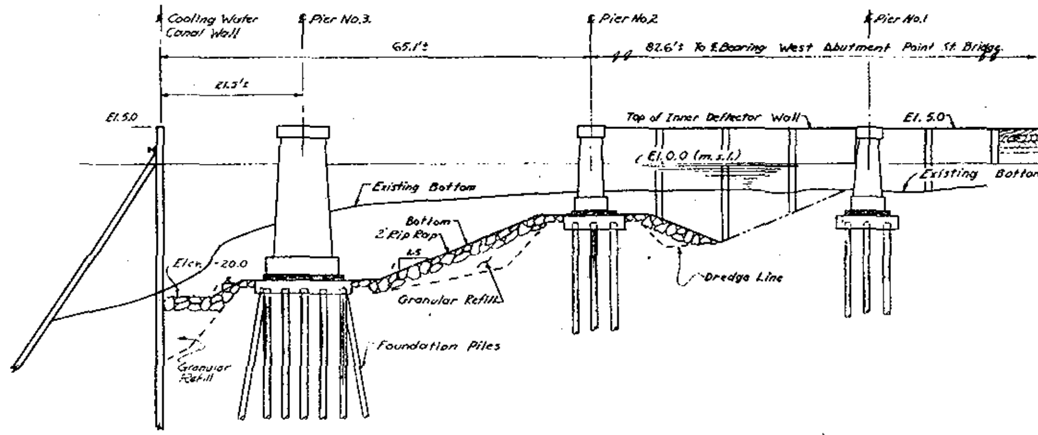
SECTION 16 AT STA. 7+82



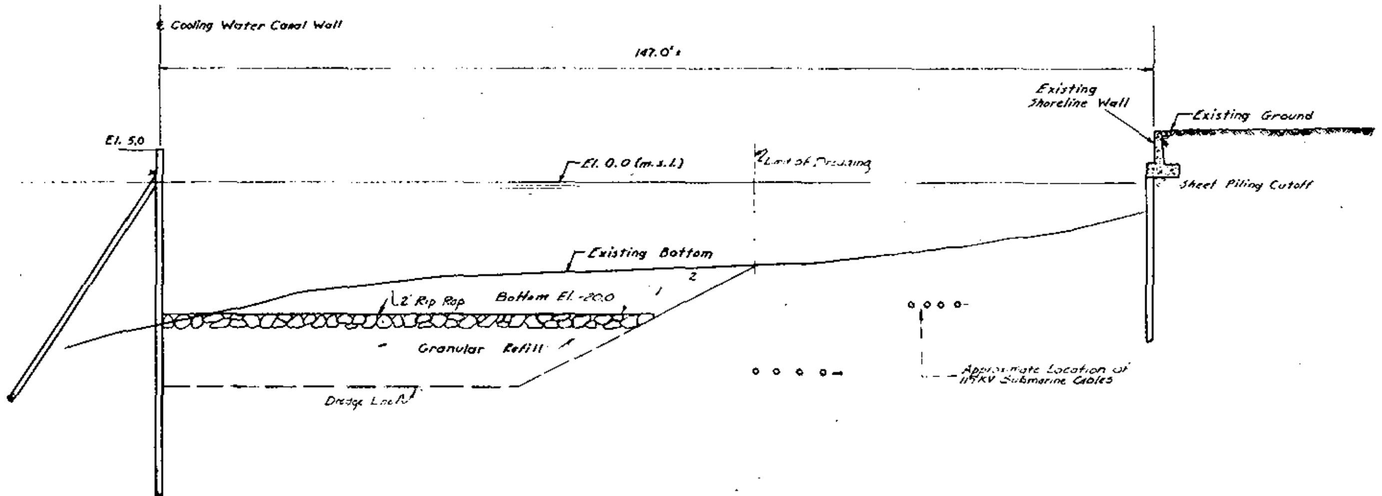
SECTION 17 AT STA. 8+28



SECTION 18 AT STA. 8+77



SECTION 19 AT STA. 9+26



SECTION 20 AT STA. 9+76

NOTES:

1. Existing Shoreline Structures Based on New England Power Service Company Drawings, Numbers H-8125-6, 50-35, 50-36; and City of Providence Drawings, Numbers 048499, 0 33778, 0 33777.
2. For location of sections, See Sheet No. 2 & 3.
3. Location of Submarine Cables based on New England Power Service Drawing No. PH-5074-5.
4. Existing River Bottom Within Cooling Water Canal, taken from Soundings and Probings, shown on sheets 2 & 3.

SCALE 1" = 10'-0"

10' 0' 10' 20'

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.R.
TRACED BY: J.F.L.
CHECKED BY: G.K.A.
SUBMITTED: S. C. Pierce
APPROVED
CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL
SECTIONS 16 THRU 20

PROVIDENCE RHODE ISLAND

APPROVED
COL. C.E. ARMY DIVISION ENGINEER

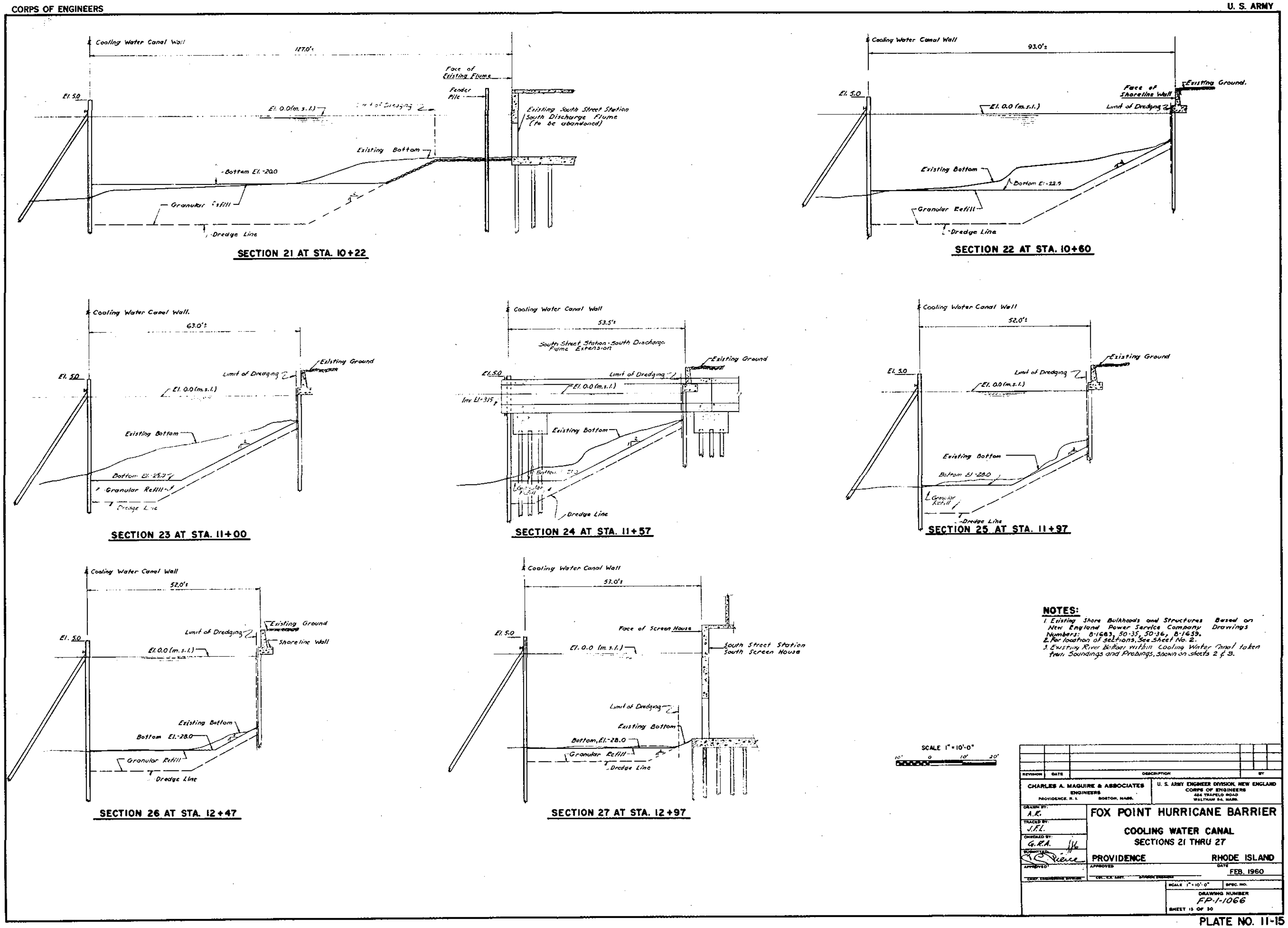
DATE FEB. 1960

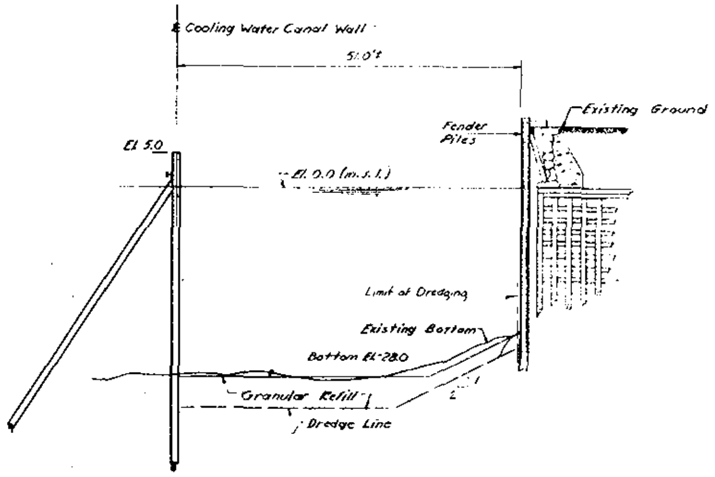
SCALE 1" = 10'-0"

SPEC. NO.

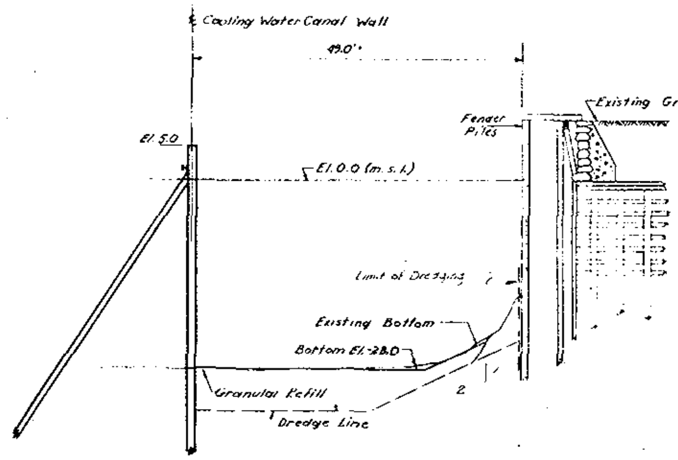
DRAWING NUMBER FP-1-1065

SHEET 14 OF 30

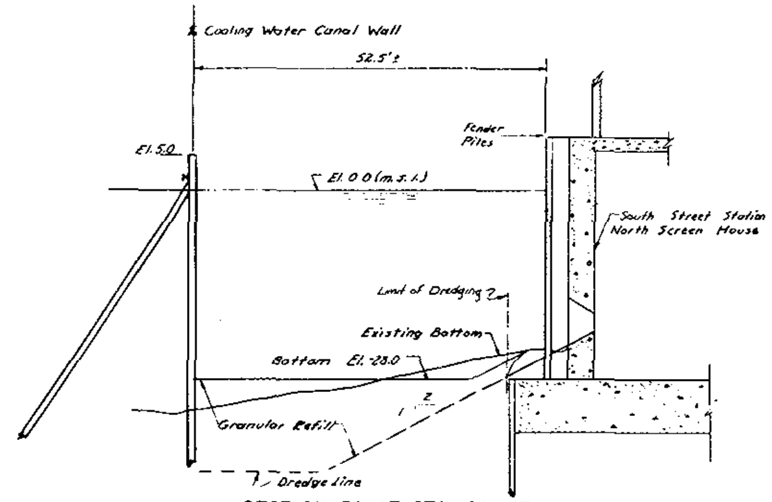

SECTION 21 AT STA. 10+22
Cooling Water Canal Wall
127.0'±
Face of Existing Flume
Fender Pile
El. 5.0
El. 0.0 (m.s.l.)
Existing South Street Station South Discharge Flume (to be abandoned)
Existing Bottom
Bottom El. -20.0
Granular Refill
Dredge Line
SECTION 22 AT STA. 10+60
93.0'±
Face of Shoreline Wall
Existing Ground
Limit of Dredging
Bottom El. -22.5
SECTION 23 AT STA. 11+00
63.0'±
SECTION 24 AT STA. 11+57
53.5'±
South Street Station South Discharge Flume Extension
SECTION 25 AT STA. 11+97
52.0'±
Bottom El. -28.0
SECTION 26 AT STA. 12+47
Shoreline Wall
SECTION 27 AT STA. 12+97
53.0'±
Face of Screen House
South Street Station South Screen House
NOTES:
1. Existing Shore Bulkheads and Structures Based on New England Power Service Company Drawings Numbers: B-1663, 50-35, 50-36, B-1659.
2. For location of sections, See Sheet No. 2.
3. Existing River Bottom within Cooling Water Canal taken from Soundings and Probings, Shown on sheets 2 & 3.
SCALE 1" = 10'-0"
CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS PROVIDENCE, R. I. BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS 424 TRAPELO ROAD WALTHAM 54, MASS.
FOX POINT HURRICANE BARRIER
COOLING WATER CANAL
SECTIONS 21 THRU 27
PROVIDENCE
RHODE ISLAND
FEB. 1960
DRAWN BY: A.K.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
DRAWING NUMBER FP-1-1066
SHEET 15 OF 30



SECTION 28 AT STA. 13+47



SECTION 29 AT STA. 13+97



SECTION 30 AT STA. 14+47

NOTES:

1. Existing Shore Bulkheads and Other Structures Based on New England Power Service Company Drawings Numbers C-4538, C-4994.
2. For location of sections, See Sheet No. 3.
3. Existing River Bottom within Cooling Water Canal, taken from Soundings and Probings, shown on sheets 2 & 3.

SCALE 1" = 10'-0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.K.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED:

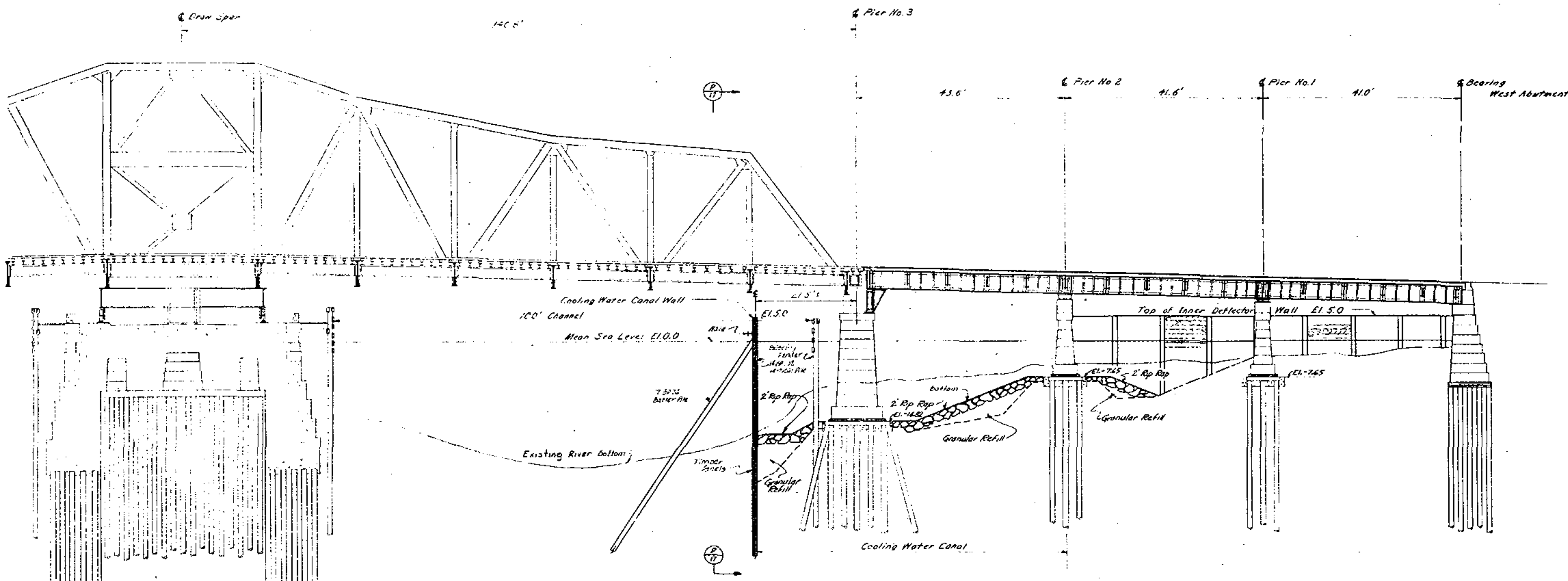
FOX POINT HURRICANE BARRIER

COOLING WATER CANAL
SECTIONS 28 THRU 30

PROVIDENCE RHODE ISLAND

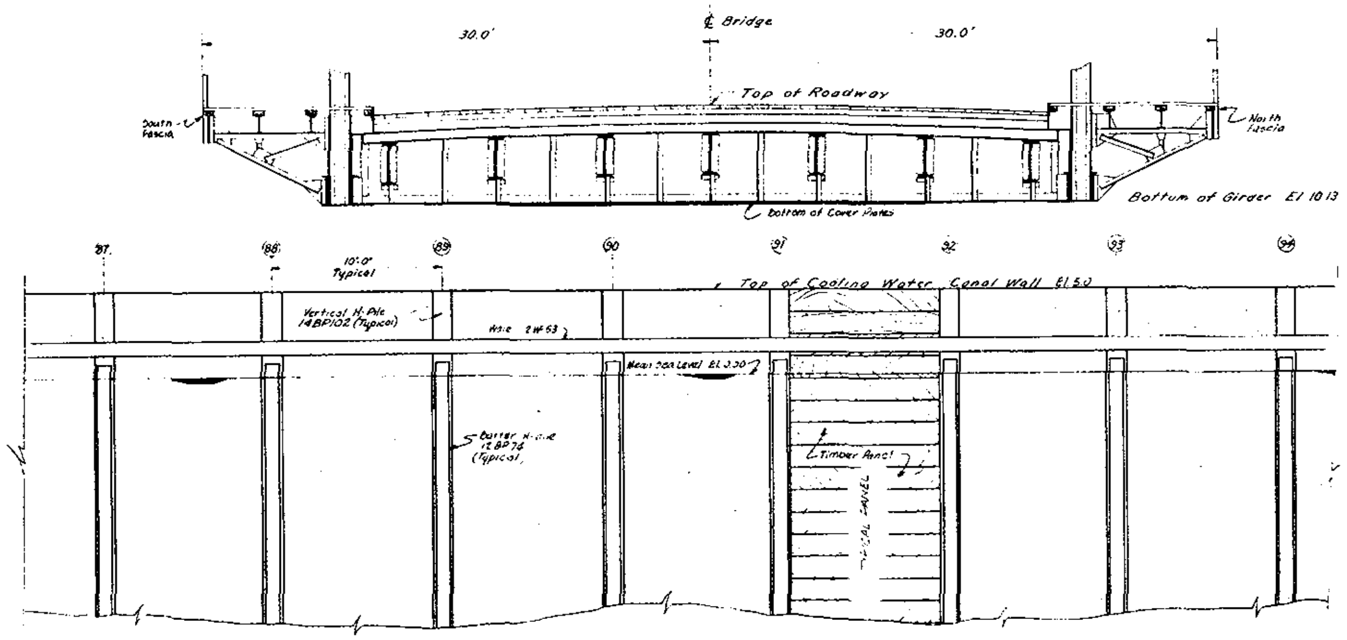
APPROVED
DATE FEB. 1960

SCALE 1" = 10'-0"
SPEC. NO.
DRAWING NUMBER FP-1-1067
SHEET 16 OF 30



LONGITUDINAL SECTION THRU ℄ POINT ST. BRIDGE

SCALE 1" = 10'



SECTION $\frac{P}{17}$

SCALE $\frac{1}{4}$" = 1'-0"

NOTES:

1. The representation on this sheet of the existing Point Street Bridge is based on the following drawings from the Engineering Department of the City of Providence, R.I.; 807-1; 807-6; 807.29; 807-33; 807-35; 807-36, 807-28; 807-31; 807-53; 807-69; 809-13; 809-16; 809-16; 809-20.
2. For other details of the Cooling Water Canal Wall see Sh.5 thru Sh.9.
3. See Sh.2 for Plan of the Cooling Water Canal Wall.

SCALE 1" = 10'

SCALE $\frac{1}{4}$" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: D. L.
TRACED BY: D. L.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED

FOX POINT HURRICANE BARRIER
COOLING WATER CANAL
SECTION THRU ℄ POINT STREET BRIDGE
PROVIDENCE RHODE ISLAND

APPROVED

DATE FEB. 1960

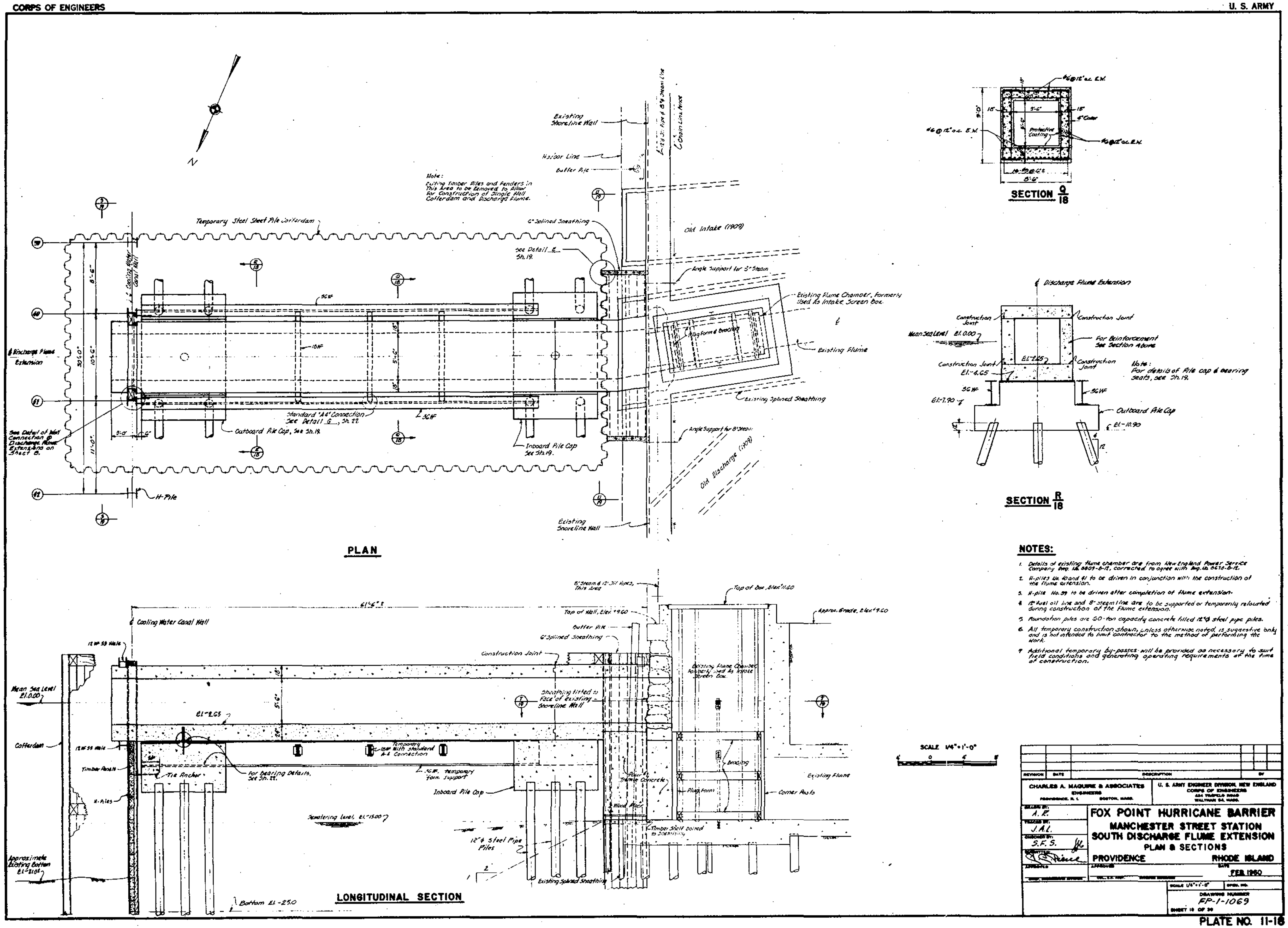
SCALE AS SHOWN

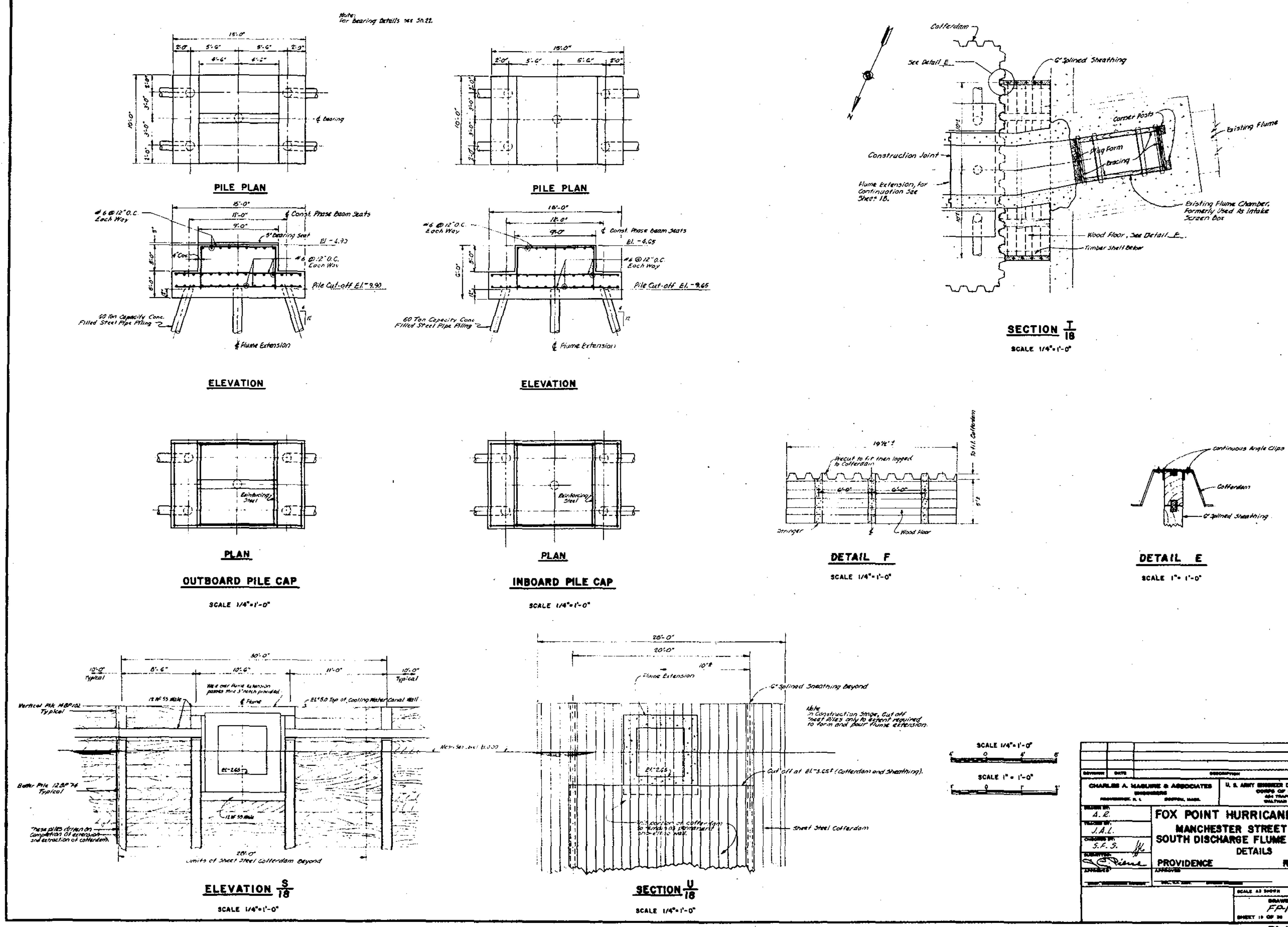
SPEC. NO.

DRAWING NUMBER FP-1-1068

SHEET 17 OF 30

PLATE NO. 11-17


N
Note:
Existing Timber Piles and Fenders in This Area to be Removed to Allow for Construction of Single Wall Cofferdam and Discharge Flume.
Existing Shoreline Wall
Harbor Line
Buffer Pile
Temporary Steel Sheet Pile Cofferdam
6" Splined Sheathing
See Detail E Sh.19.
Old Intake (1909)
Angle Support for 8" Steam
Existing Flume Chamber, Formerly Used As Intake Screen Box.
Existing Flume
Existing Splined Sheathing
Angle Support for 8" Steam
Old Discharge (1909)
Cooling Water Canal Wall
℄ Discharge Flume Extension
Standard "A4" Connection See Detail G Sh.22
Outboard Pile Cap, See Sh.19.
Inboard Pile Cap See Sh.19.
See Detail of Wall Connection @ Discharge Flume Extension on Sheet 8.
H-Pile
PLAN
SECTION Q/18
SECTION R/18
Construction Joint
Mean Sea Level El.0.00
For Reinforcement See Section Above
Note: For details of Pile cap & bearing seats, see Sh.19.
Outboard Pile Cap
LONGITUDINAL SECTION
Top of Box, Elev.+11.60
Approx. Grade, Elev.+9.00
Top of Wall, Elev.+9.60
Buffer Pile
6" Splined Sheathing
Construction Joint
Existing Flume Chamber formerly Used As Intake Screen Box.
Sheathing fitted to Face of Existing Shoreline Wall
Cofferdam
Timber Ranger
Tie Anchor
H-Piles
For Bearing Details, See Sh.22.
Inboard Pile Cap
Dewatering Level, EL-15.00
12"⌀ Steel Pipe Piles
Approximate Existing Bottom
Bottom EL-25.0
Existing Splined Sheathing
Timber Shell bolted to Sheathing
Corner Posts
Existing Flume
bracing
Plug form
SCALE 1/4" = 1'-0"
NOTES:
1. Details of existing flume chamber are from New England Power Service Company Dwg. No. 8809-B-12, corrected to agree with Dwg. No. 0614-B-12.
2. H-piles No. 40 and 41 to be driven in conjunction with the construction of the flume extension.
3. H-pile No. 39 to be driven after completion of flume extension.
4. 12" fuel oil line and 8" steam line are to be supported or temporarily relocated during construction of the flume extension.
5. Foundation piles are 60-ton capacity concrete filled 12"⌀ steel pipe piles.
6. All temporary construction shown, unless otherwise noted, is suggestive only and is not intended to limit contractor to the method of performing the work.
7. Additional temporary by-passes will be provided as necessary to suit field conditions and generating operating requirements at the time of construction.
REVISION
DATE
DESCRIPTION
BY
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I.
BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.
A. R.
J.A.L.
S.F.S.
FOX POINT HURRICANE BARRIER
MANCHESTER STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
PLAN & SECTIONS
PROVIDENCE
RHODE ISLAND
FEB 1960
SCALE 1/4" = 1'-0"
DRAWING NUMBER
FP-1-1069
SHEET 18 OF 30



CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM 54, MASS.

DRAWN BY: A. R.
TRACED BY: J.A.L.
CHECKED BY: S.F.S.

FOX POINT HURRICANE BARRIER

MANCHESTER STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
DETAILS

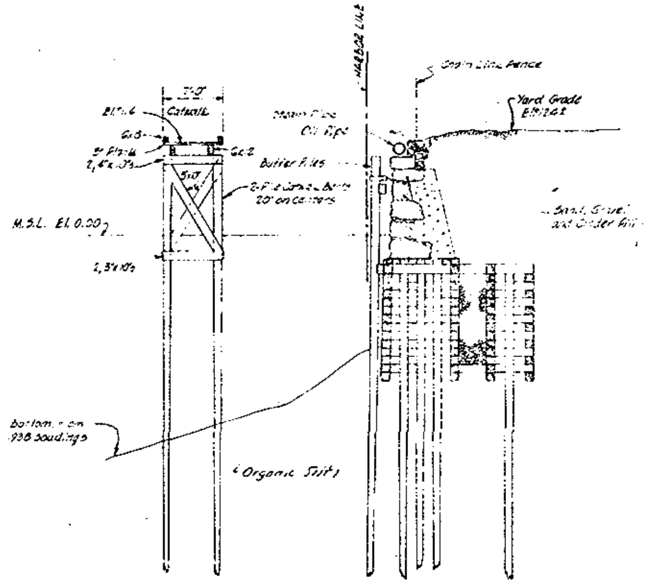
PROVIDENCE RHODE ISLAND

FEB. 1960

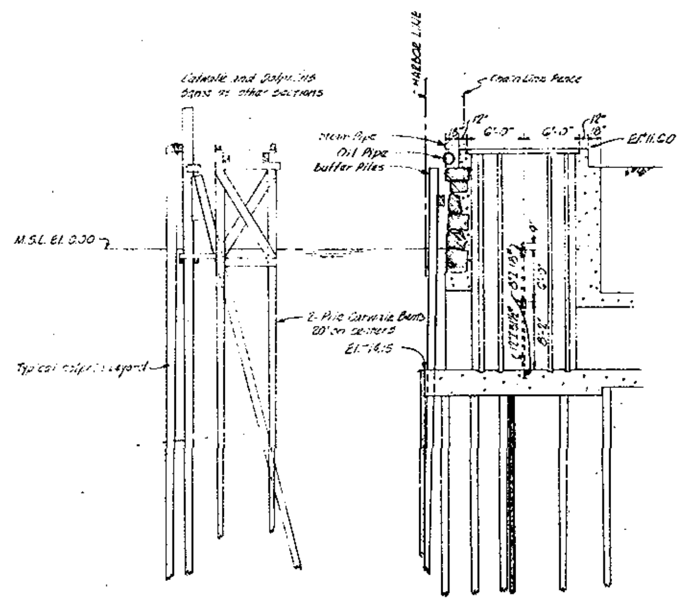
SCALE AS SHOWN

DRAWING NUMBER FP-1-1070

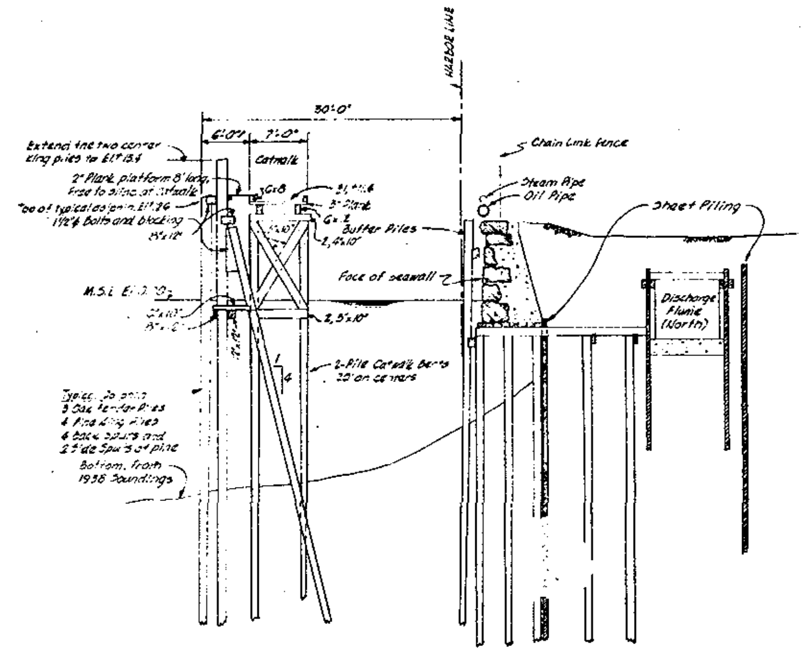
SHEET 19 OF 26



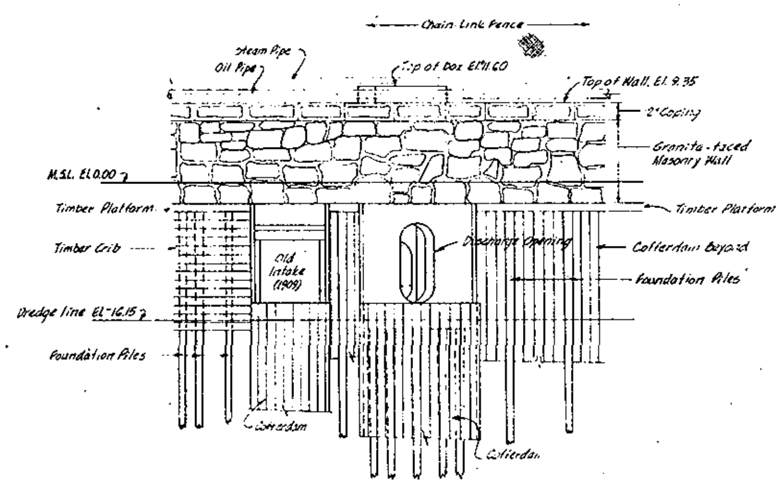
SECTION SOUTH OF EXISTING FLUME CHAMBER



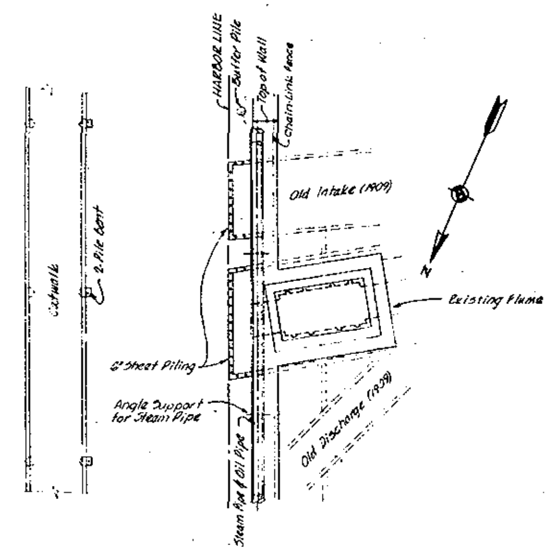
SECTION THRU EXISTING FLUME CHAMBER



SECTION NORTH OF EXISTING FLUME CHAMBER



ELEVATION OF EXISTING FLUME CHAMBER



PLAN OF EXISTING FLUME CHAMBER

NOTES

1. Sections, details and notes represented on this sheet are taken from the listed Reference Drawings. Existing conditions to be verified by contractor in field.

SCALE 1/8" = 1'-0"

Reference Drawings
New England Power Service Company Dwg. No. H-18377-2
do do 8673 B-12
do do 8809 B-12
do do 8115 B-12
do do H-8125-0
do do H-7641-0
Photostat labelled "Rhode Island Suburban Railway Co., Power House On Manchester St."
do "Manchester St. Waterfront Development".

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A. E.
TRACED BY: J.A.L.
CHECKED BY: S.F.S.
SUBMITTED:
APPROVED

FOX POINT HURRICANE BARRIER
MANCHESTER STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
EXISTING DETAILS

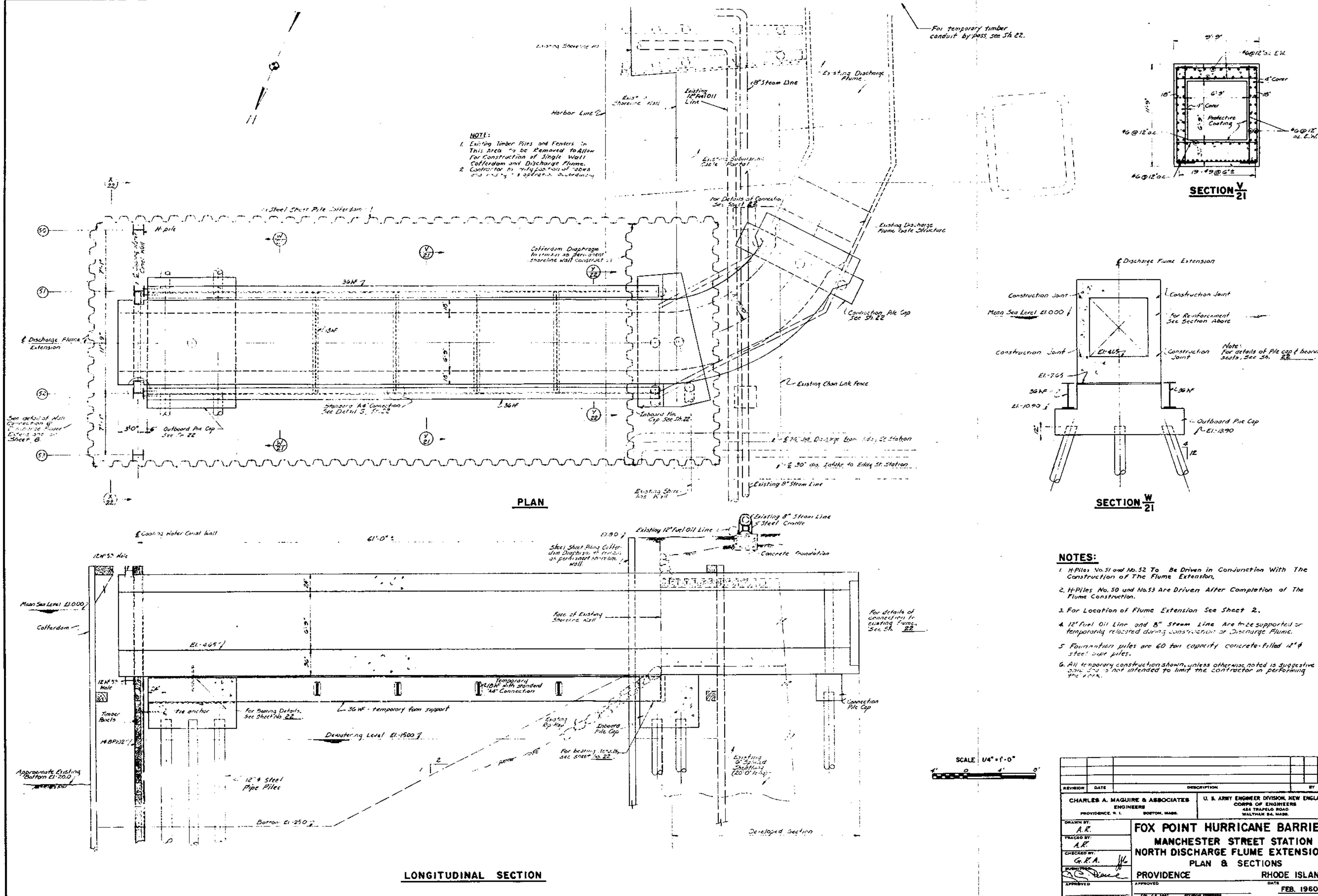
PROVIDENCE RHODE ISLAND

APPROVED
DATE FEB. 1960

SCALE 1/8" = 1'-0" SPEC. NO.

DRAWING NUMBER FP-1-1071

SHEET 20 OF 30



NOTES:

1. H-Piles No. 51 and No. 52 To Be Driven in Conjunction With The Construction of The Flume Extension.
2. H-Piles No. 50 and No. 53 Are Driven After Completion of The Flume Construction.
3. For Location of Flume Extension See Sheet 2.
4. 12" Fuel Oil Line and 8" Steam Line Are to be supported or temporarily relocated during construction of Discharge Flume.
5. Foundation piles are 60 ton capacity concrete-filled 12" ф steel pipe piles.
6. All temporary construction shown, unless otherwise noted is suggestive only and is not intended to limit the contractor in performing the work.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: A.R.
TRACED BY: A.R.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED
CHIEF, ENGINEERING DIVISION

FOX POINT HURRICANE BARRIER
MANCHESTER STREET STATION
NORTH DISCHARGE FLUME EXTENSION
PLAN & SECTIONS

PROVIDENCE RHODE ISLAND

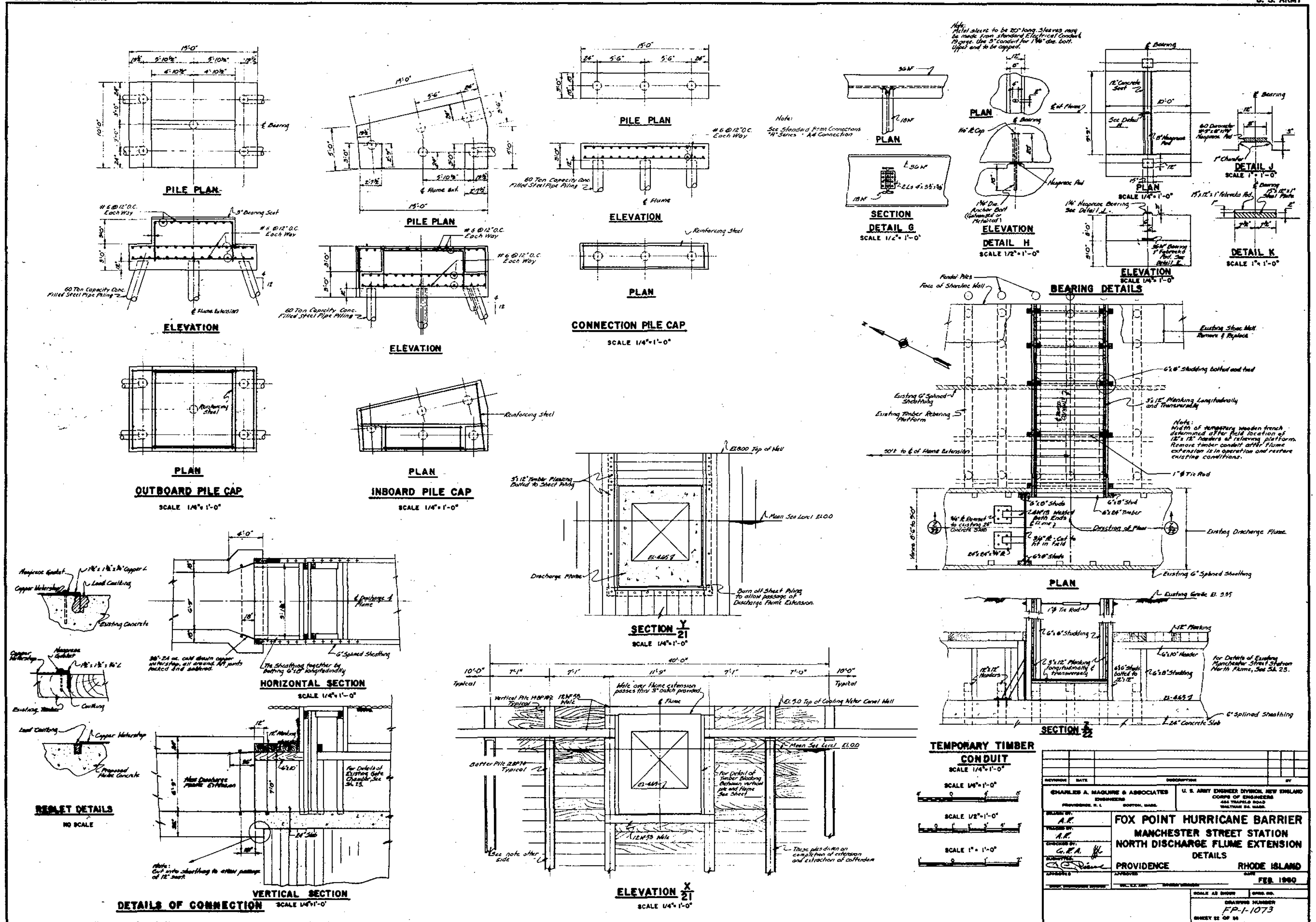
APPROVED
COL., C.E. ASST. DIVISION ENGINEER

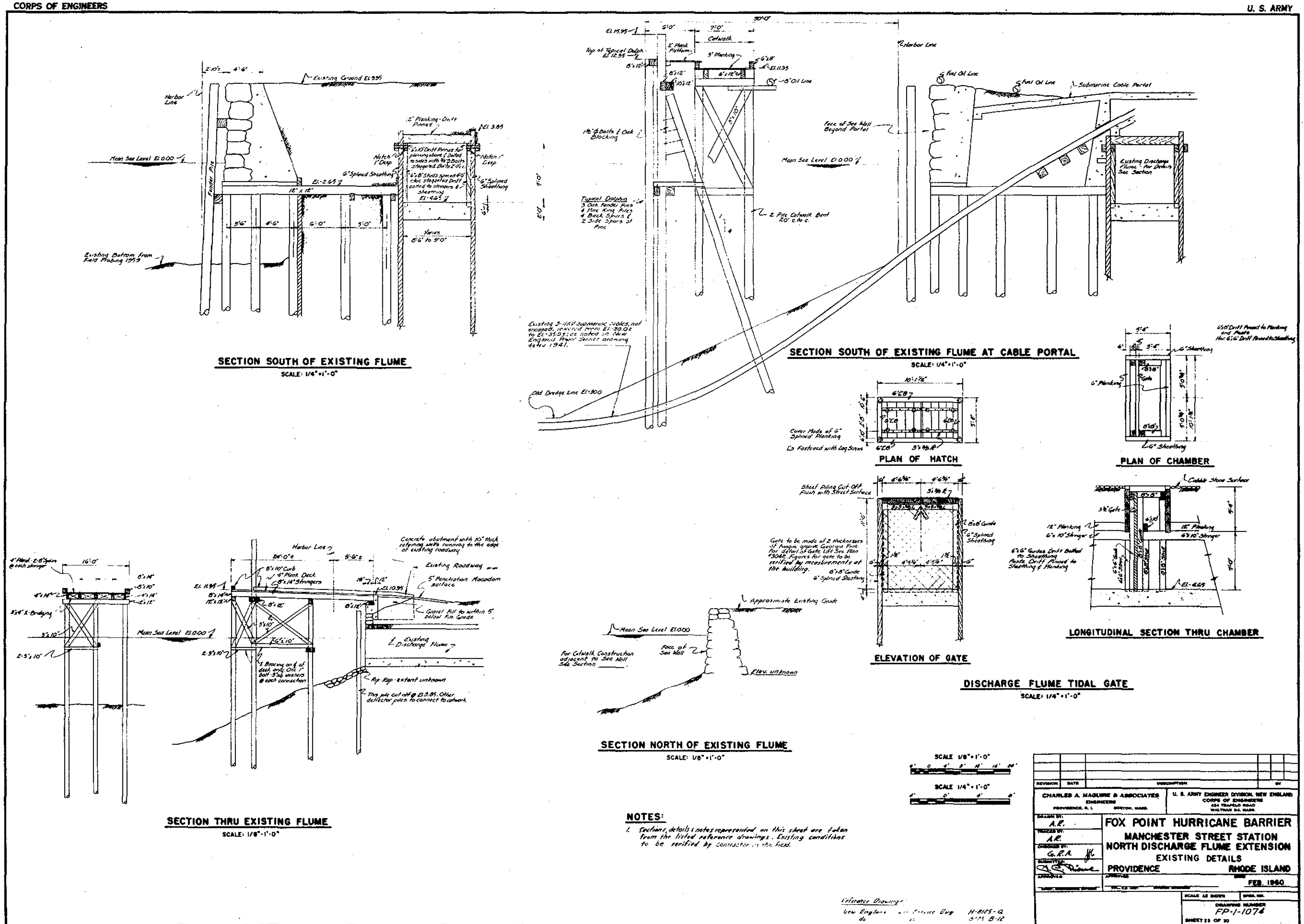
DATE FEB. 1960

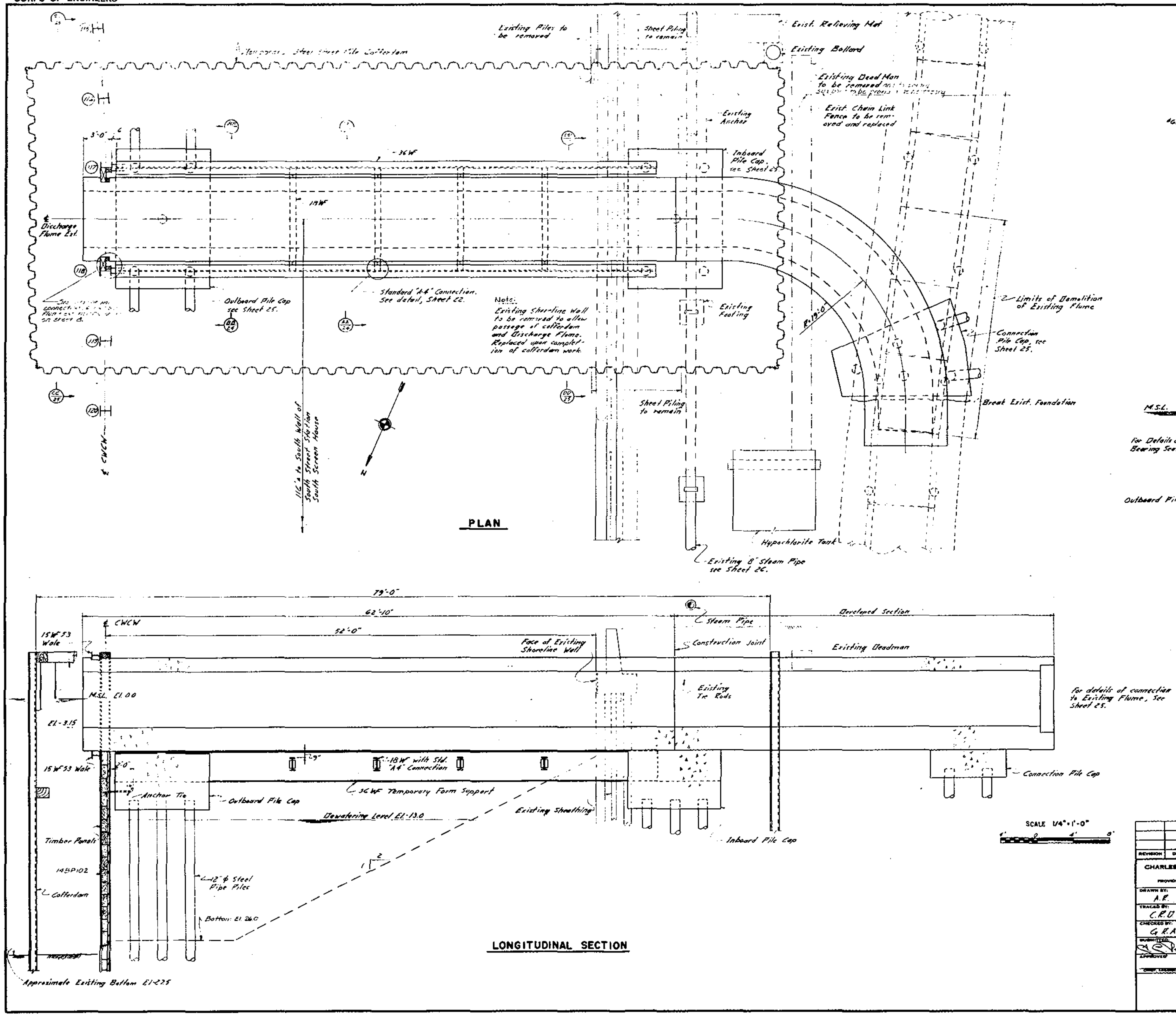
SCALE 1/4" = 1'-0" SPEC. NO.

DRAWING NUMBER FP-1-1072

SHEET 21 OF 30


PILE PLAN
ELEVATION
OUTBOARD PILE CAP
SCALE 1/4"=1'-0"
PILE PLAN
ELEVATION
PLAN
INBOARD PILE CAP
SCALE 1/4"=1'-0"
PILE PLAN
ELEVATION
PLAN
CONNECTION PILE CAP
SCALE 1/4"=1'-0"
PLAN
SECTION
DETAIL G
SCALE 1 1/2"=1'-0"
PLAN
ELEVATION
DETAIL H
SCALE 1/2"=1'-0"
PLAN
SCALE 1/4"=1'-0"
ELEVATION
SCALE 1/4"=1'-0"
DETAIL J
SCALE 1"=1'-0"
DETAIL K
SCALE 1"=1'-0"
BEARING DETAILS
PLAN
SECTION Y/21
SCALE 1/4"=1'-0"
HORIZONTAL SECTION
SCALE 1/4"=1'-0"
VERTICAL SECTION
SCALE 1/4"=1'-0"
DETAILS OF CONNECTION
REGLET DETAILS
NO SCALE
ELEVATION X/21
SCALE 1/4"=1'-0"
SECTION Z/22
TEMPORARY TIMBER CONDUIT
SCALE 1/4"=1'-0"
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I.
BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
FOX POINT HURRICANE BARRIER
MANCHESTER STREET STATION
NORTH DISCHARGE FLUME EXTENSION
DETAILS
PROVIDENCE
RHODE ISLAND
FEB. 1960
FP-1-1073


SECTION SOUTH OF EXISTING FLUME
SCALE: 1/4" = 1'-0"
SECTION SOUTH OF EXISTING FLUME AT CABLE PORTAL
SCALE: 1/4" = 1'-0"
PLAN OF HATCH
PLAN OF CHAMBER
ELEVATION OF GATE
LONGITUDINAL SECTION THRU CHAMBER
DISCHARGE FLUME TIDAL GATE
SCALE: 1/4" = 1'-0"
SECTION NORTH OF EXISTING FLUME
SCALE: 1/8" = 1'-0"
SECTION THRU EXISTING FLUME
SCALE: 1/8" = 1'-0"
SCALE 1/8" = 1'-0"
SCALE 1/4" = 1'-0"
NOTES:
1. Sections, details & notes represented on this sheet are taken from the listed reference drawings. Existing conditions to be verified by contractor in the field.
CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.
DRAWN BY: A.R.
TRACED BY: A.R.
CHECKED BY: G.R.A.
FOX POINT HURRICANE BARRIER
MANCHESTER STREET STATION
NORTH DISCHARGE FLUME EXTENSION
EXISTING DETAILS
PROVIDENCE RHODE ISLAND
FEB. 1960
SCALE AS SHOWN
DRAWING NUMBER
FP-1-1074
SHEET 23 OF 30



NOTES:

1. H-piles No. 17 & 18 to be driven in conjunction with the construction of the Flume Extension.
2. H-piles No. 16 & 19 are to be driven after completion of the Flume Construction.
3. For location of Flume Extension, see Sheet 3.
4. 8" Steam Line is to be supported or temporarily relocated during the construction of the Flume Extension.
5. Foundation piles are 60 ton capacity concrete filled 12" ϕ steel pipe piles.
6. All temporary construction shown, unless otherwise noted is suggestive only, and is not intended to limit the contractor to the method of performing the work.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS PROVIDENCE, R.I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS 424 TRAPELO ROAD WALTHAM 54, MASS.

DRAWN BY: A.F.
TRACED BY: C.R.D.
CHECKED BY: G.R.A.

FOX POINT HURRICANE BARRIER
SOUTH STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
PLAN & SECTIONS

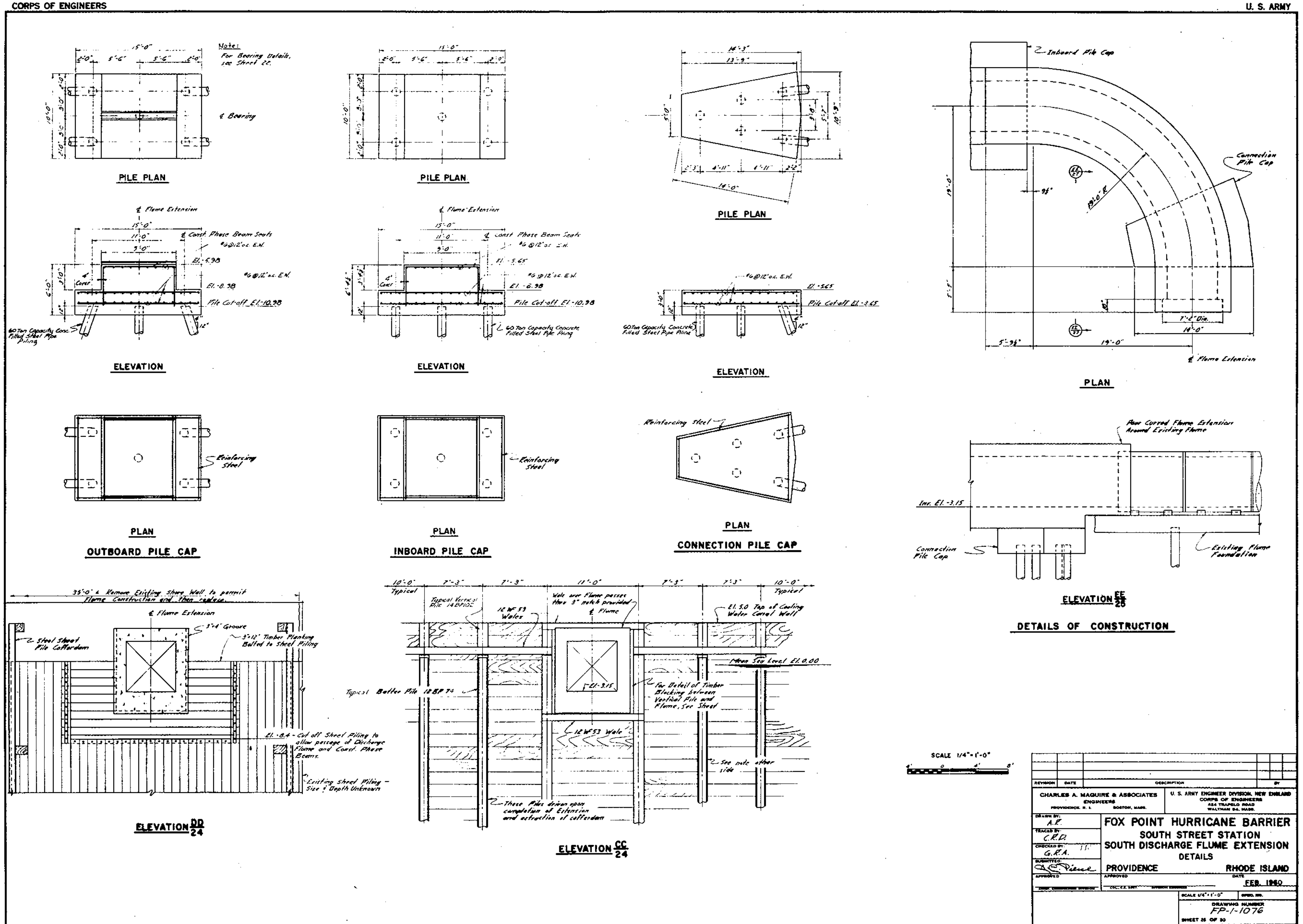
PROVIDENCE RHODE ISLAND

FEB. 1960

SCALE 1/4" = 1'-0"

DRAWING NUMBER FP-1-1075

SHEET 24 OF 30



REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES, ENGINEERS, PROVIDENCE, R. I. / BOSTON, MASS.

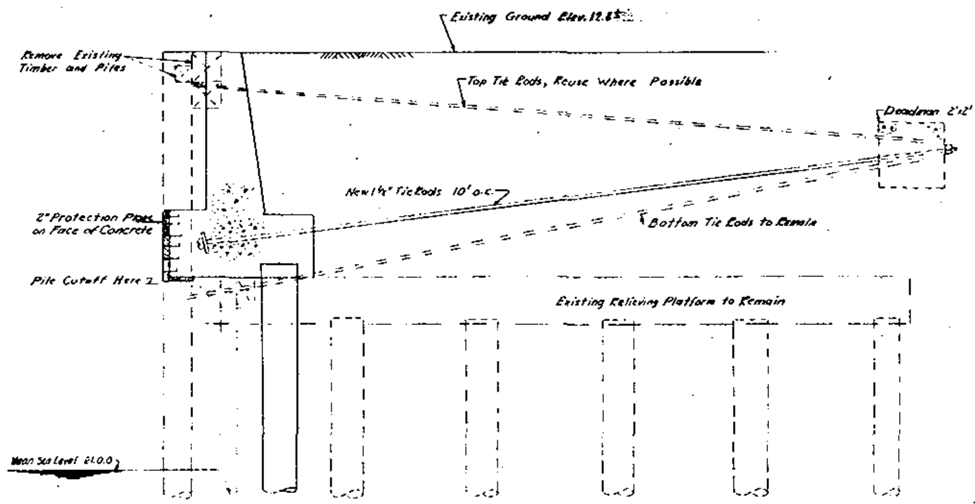
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND, CORPS OF ENGINEERS, 424 TRAPELO ROAD, WALTHAM 54, MASS.

DRAWN BY: A.F.
TRACED BY: C.R.D.
CHECKED BY: G.R.A.
SUBMITTED: [signature]
APPROVED:

FOX POINT HURRICANE BARRIER
SOUTH STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
DETAILS

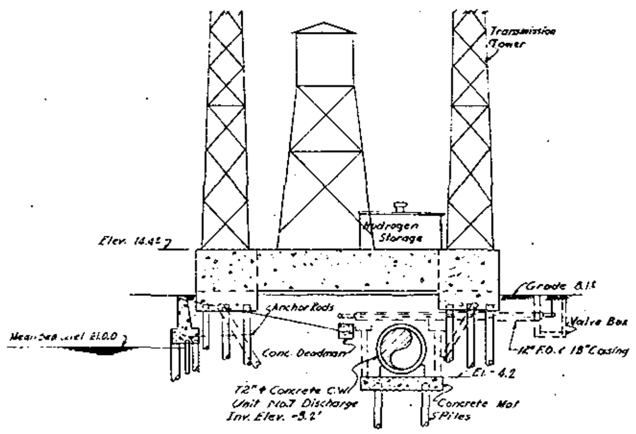
PROVIDENCE — RHODE ISLAND

DATE: FEB. 1960
SCALE: 1/4"=1'-0"
DRAWING NUMBER: FP-1-1076
SHEET 25 OF 30



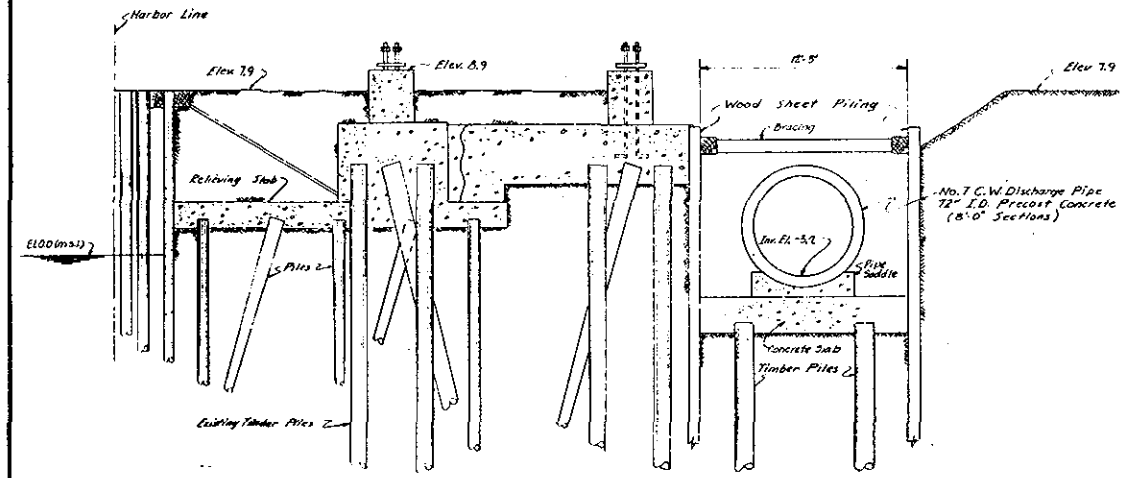
SECTION THRU SHORE AT LOCATION OF PROPOSED FLUME EXTENSION

SCALE 1/2"=1'-0"



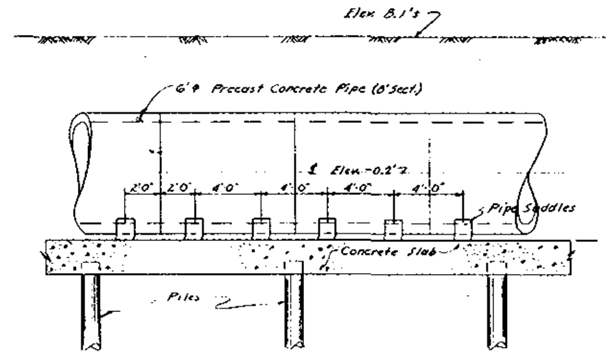
SECTION THRU SHORE NORTH OF PROPOSED FLUME EXTENSION

SCALE 1"=10'-0"



SECTION THRU SHORE SOUTH OF PROPOSED FLUME EXTENSION

SCALE 1/2"=1'-0"

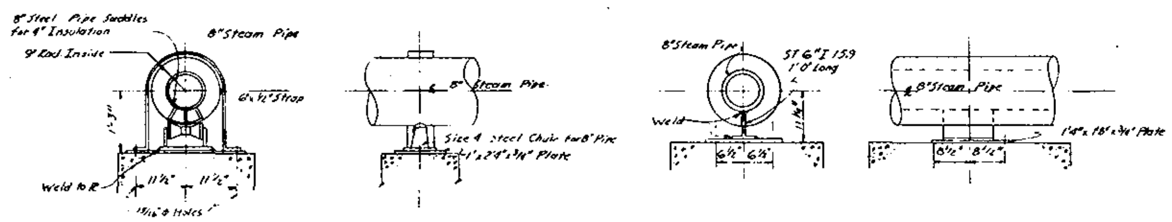


ELEVATION OF EXISTING DISCHARGE PIPE

SCALE 1/4"=1'-0"

NOTES:

1. Sections, details and notes represented on this sheet are taken from the listed Reference Drawings. Actual existing conditions must be verified by contractor in field.



SECTION | ELEVATION | SECTION | ELEVATION

NORMAL SADDLE | ANCHOR SADDLE

EXISTING 8-INCH STEAM LINE

SCALE 3/4"=1'-0"

Reference Drawings

New England Power Service Company No. 1667
Do. No. 1847
Do No. 16267
Do No. 18377-2
Do. No. 50-36

SCALE 1"=10'-0"

SCALE 1/4"=1'-0"

SCALE 1/2"=1'-0"

SCALE 3/4"=1'-0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: J.F.L.
TRACED BY: J.F.L.
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED:

FOX POINT HURRICANE BARRIER
SOUTH STREET STATION
SOUTH DISCHARGE FLUME EXTENSION
EXISTING DETAILS

PROVIDENCE RHODE ISLAND

APPROVED

DATE FEB. 1960

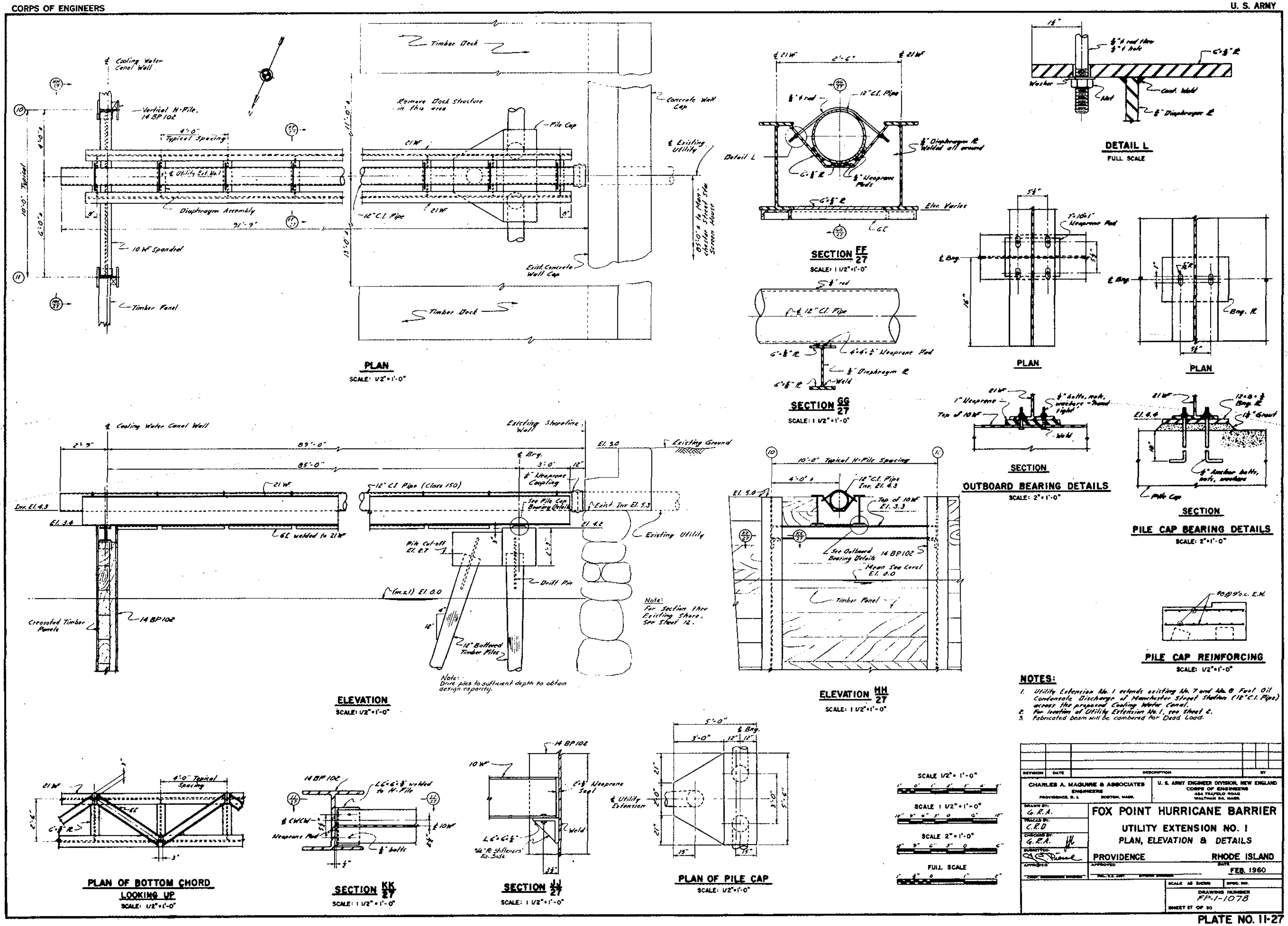
SCALE AS SHOWN | SPEC. NO.

DRAWING NUMBER FP-1-1077

SHEET 26 OF 30

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

1. Utility Extension No. 1 extends existing No. 7 and No. 8 Fuel Oil Condensate Discharge of Manchester Street Station (18" C.I. Pipe) across the proposed Cooling Water Canal.
2. For location of Utility Extension No. 1, see Sheet 2.
3. Fabricated beam will be cambered for Dead Load.

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES ENGINEERS — PROVIDENCE, R. I. — BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND, CORPS OF ENGINEERS, 424 TRAPELO ROAD, WALTHAM 54, MASS.

DRAWN BY: G.R.A.
TRACED BY: C.R.D
CHECKED BY: G.R.A.
SUBMITTED:
APPROVED

FOX POINT HURRICANE BARRIER

UTILITY EXTENSION NO. 1

PLAN, ELEVATION & DETAILS

PROVIDENCE RHODE ISLAND

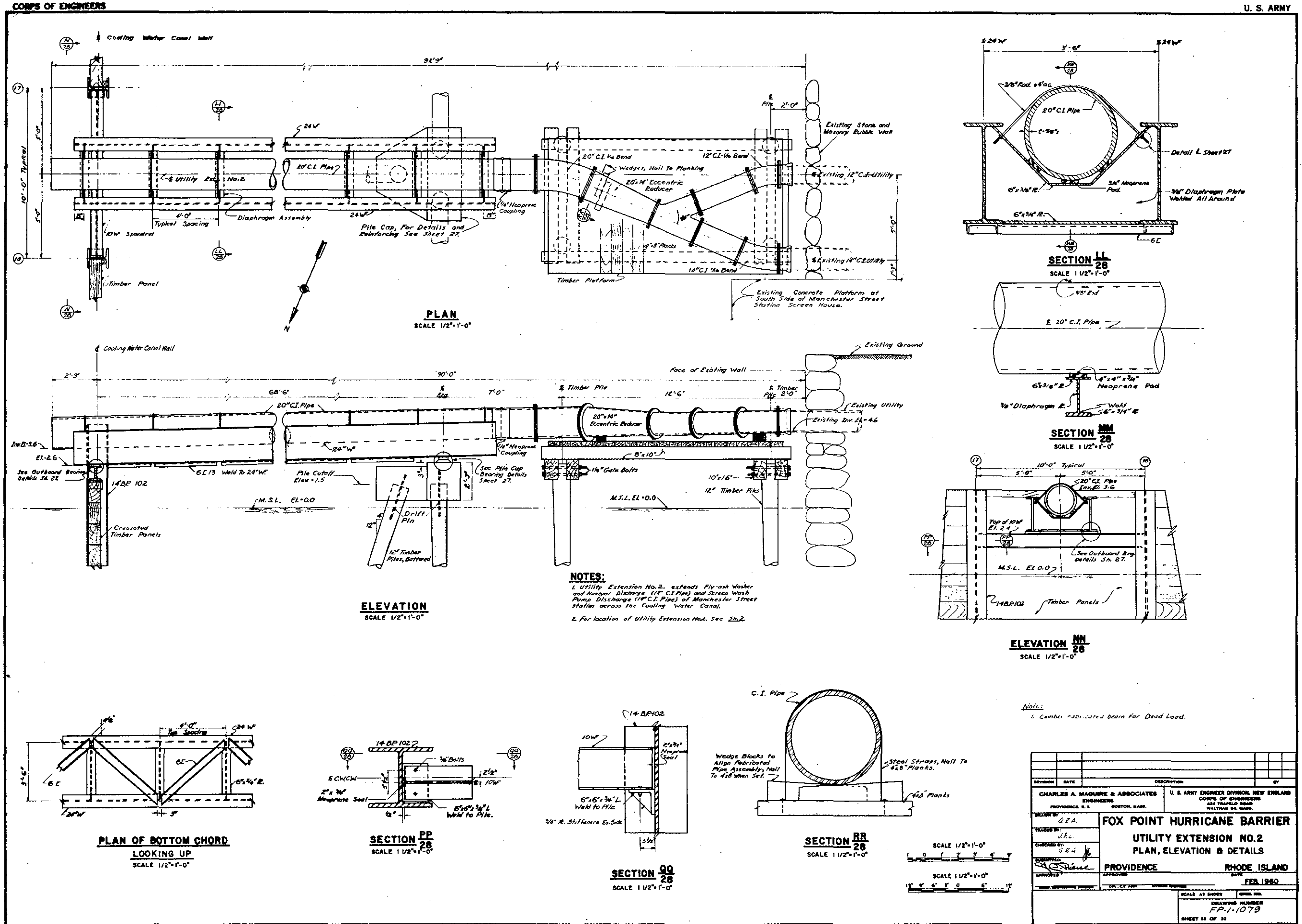
DATE FEB. 1960

SCALE AS SHOWN — SPEC. NO.

DRAWING NUMBER FP-1-1078

SHEET 27 OF 30

PLATE NO. 11-27



NOTES:

1. Utility Extension No.2. extends Fly-ash Washer and Nuveyor Discharge (12" C.I.Pipe) and Screen Wash Pump Discharge (14" C.I. Pipe) of Manchester Street Station across the Cooling Water Canal.
2. For location of Utility Extension No.2, See Sh.2.

Note:
1. Camber fabricated beam for Dead Load.

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: G.E.A.
TRACED BY: J.F.L.
CHECKED BY: G.E.A.

FOX POINT HURRICANE BARRIER

UTILITY EXTENSION NO.2

PLAN, ELEVATION & DETAILS

PROVIDENCE RHODE ISLAND

DATE FEB. 1960

SCALE AS SHOWN

DRAWING NUMBER FP-1-1079

SHEET 28 OF 30

PLATE NO. 11-28

CORPS OF ENGINEERS

U. S. ARMY

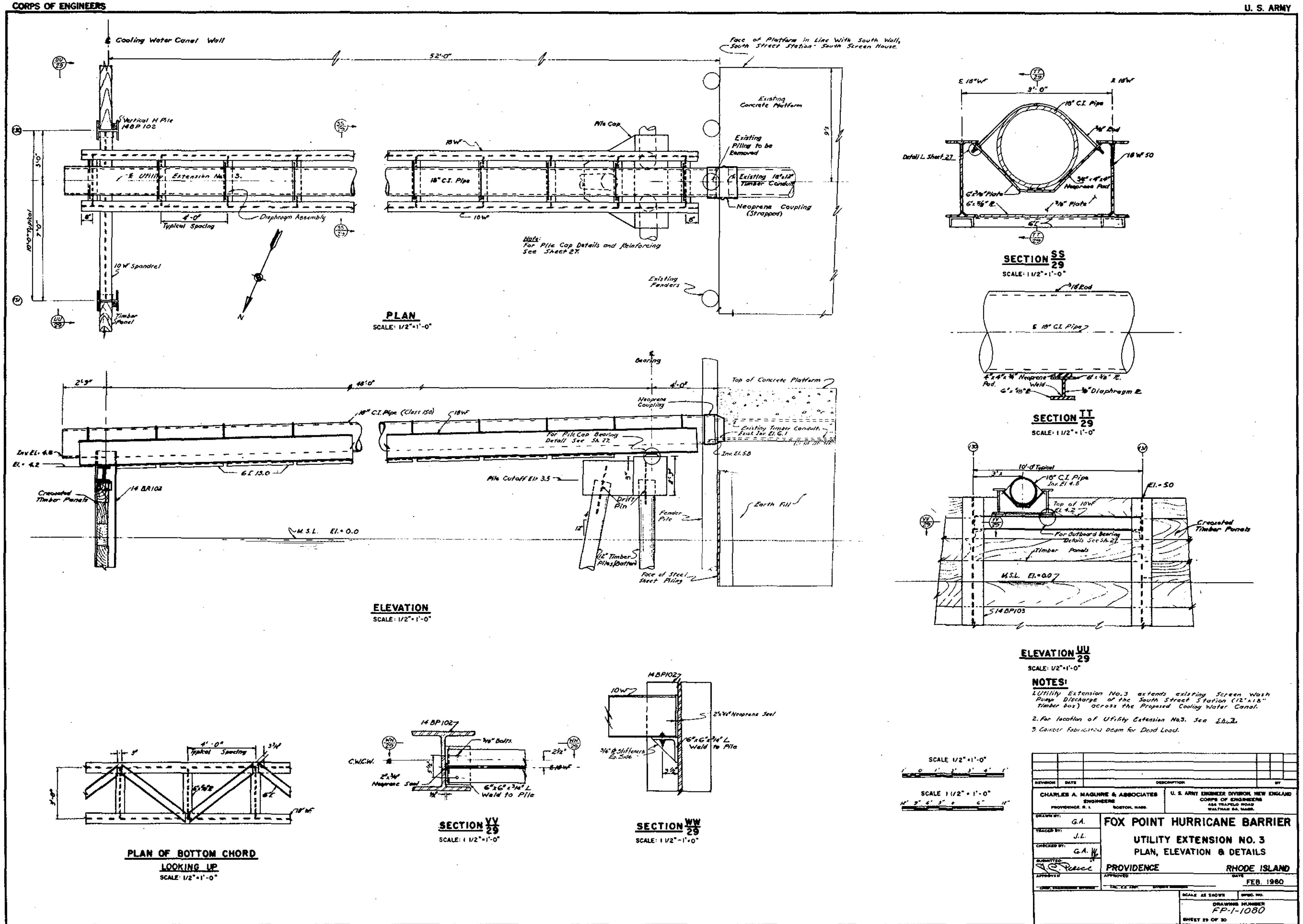
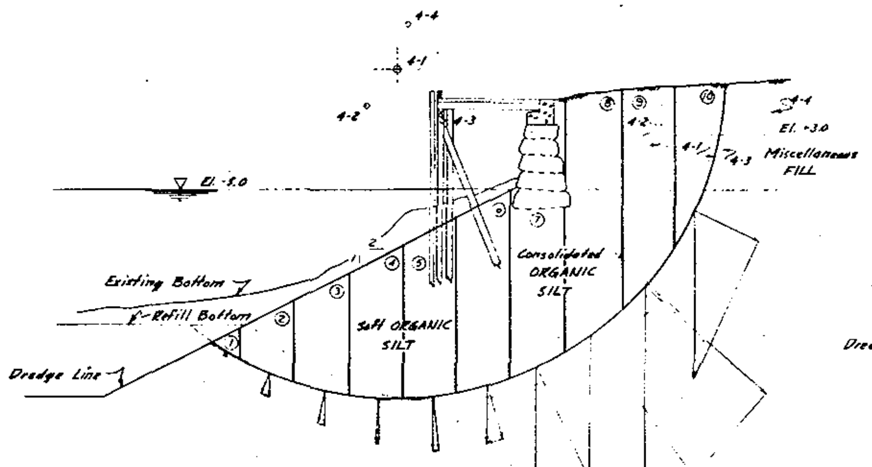


PLATE NO. 11-29

CORPS OF ENGINEERS | U. S. ARMY



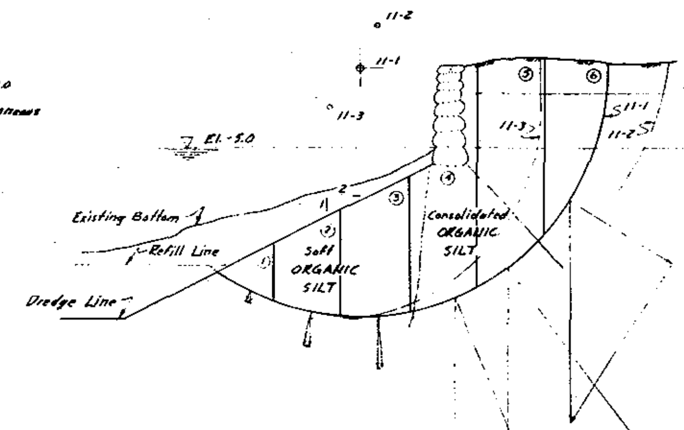
SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.2	-0.1	0.2	0	0
2	0.9	-0.4	0.9	0	0
3	1.3	-0.3	1.3	0	0
4	1.7	-0.2	1.7	0	0
5	2.0	0.2	2.0	0	0
6	2.1	0.6	2.1	0	0
7	11.1	4.8	10.0	2.7	4.5
8	9.4	5.6	7.6	2.1	4.5
9	9.2	6.8	6.2	3.6	2.5
10	6.2	5.7	2.7	1.6	0
TOTAL		22.7		10.0	11.5

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{10.0 + 11.5}{22.7} = 0.95$

SUMMARY OF TRIALS	
Arc.	S.F.
4-1	0.95
4-2	0.99
4-3	0.99
4-4	1.10
Existing	1.02

SECTION 4 AT STA. 2+02



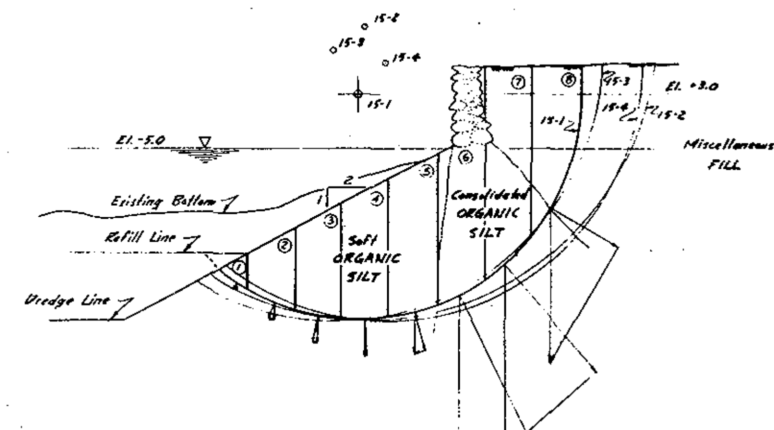
SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.4	-0.2	0.4	0	0
2	1.3	-0.3	1.1	0	0
3	1.8	0.2	1.8	0	0
4	12.8	5.0	11.8	3.1	5.0
5	12.0	7.3	9.5	2.5	6.0
6	8.3	7.0	4.5	2.6	0
TOTAL		19.0		8.2	11.0

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{8.2 + 11.0}{19.0} = 1.01$

SUMMARY OF TRIALS	
Arc.	S.F.
11-1	1.01
11-2	1.22
11-3	1.33
Existing	1.15

SECTION 11 AT STA. 5+58



SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.1	-0.1	0.1	0	0
2	0.6	-0.2	0.6	0	0
3	1.0	-0.2	1.0	0	0
4	1.4	0.1	1.4	0	0
5	1.5	0.4	1.5	0	0
6	7.1	3.3	6.2	1.6	4.0
7	7.0	4.7	5.2	1.4	4.5
8	5.8	5.1	2.9	1.4	2.0
TOTAL		13.1		4.4	10.5

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{4.4 + 10.5}{13.1} = 1.12$

SUMMARY OF TRIALS	
Arc.	S.F.
15-1	1.12
15-2	1.15
15-3	1.16
15-4	1.15
Existing	1.08

SECTION 15 AT STA. 7+38

DESIGN DATA

	γsat, pcf	γbuoy, pcf	ϕ°	c, TSF
Soft ORGANIC SILT	85	20	0	0
Consolidated ORGANIC SILT	100	38	15	0.5
Miscellaneous FILL	115	50	30	0

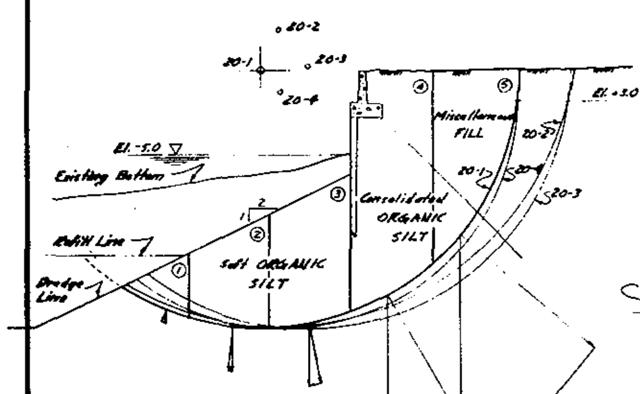
γ moist = 115 pcf
γ damp = 110 pcf

LEGEND

- W — Effective weight of material in slice.
- T — Tangential component of effective weight in slice.
- Fn — Normal soil force on base of slice.
- c — Unit cohesion of soil in slice.
- C — Total cohesion on base of slice = Unit Cohesion × Length of Arc
- ϕ — Angle of internal friction of soil in slice.
- ◆ — Center of critical circle of failure
- • — Center of other trial circles
- ▽ — Assumed water level.

NOTES:

1. Scale for force vectors: 1 inch = 2.5 tons.
2. Miscellaneous FILL considered as damp above Elev. +3.0 and as moist between Elev. +3.0 and Elev. -5.0.
3. Trials as shown are for the condition after dredging and prior to refill, except as noted.



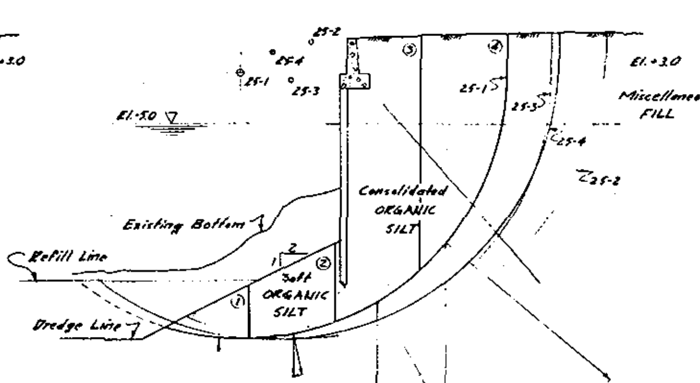
SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.5	-0.2	0.4	0	0
2	1.6	-0.1	1.6	0	0
3	2.3	0.5	2.2	0	0
4	11.7	5.9	10.1	2.7	6.5
5	10.1	7.9	6.3	2.7	4.5
TOTAL		14.0		5.4	11.0

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{5.4 + 11.0}{14.0} = 1.16$

SUMMARY OF TRIALS	
Arc	S.F.
20-1	1.16
20-2	1.25
20-3	1.29
20-4	1.29
Existing	1.30

SECTION 20 AT STA. 9+76



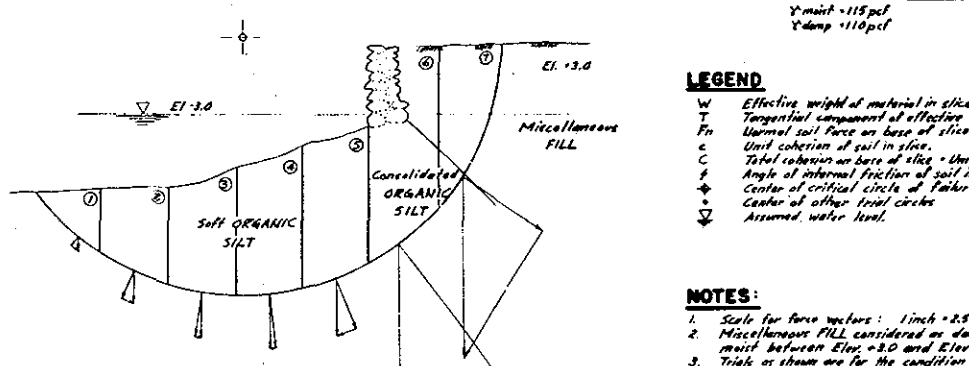
SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.5	-0.1	0.5	0	0
2	1.2	0.2	1.1	0	0
3	14.1	7.3	12.0	3.2	7.5
4	12.4	9.6	8.0	3.3	6.0
TOTAL		17.0		6.5	13.5

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{6.5 + 13.5}{17.0} = 1.16$

SUMMARY OF TRIALS	
Arc	S.F.
25-1	1.16
25-2	1.33
25-3	1.21
25-4	1.22
Existing	1.03

SECTION 25 AT STA. 11+97



SUMMARY OF FORCES - TONS					
Slice	W	T	Fn	Fn Tan ϕ	C
1	0.5	-0.3	0.4	0	0
2	1.2	-0.5	1.1	0	0
3	1.8	-0.3	1.8	0	0
4	2.0	0.2	2.0	0	0
5	2.0	0.8	2.0	0	0
6	10.3	6.5	8.1	2.1	6.5
7	6.7	5.7	3.5	1.5	3.0
TOTAL		12.1		3.6	9.5

Safety Factor $= \frac{\Sigma Fn \tan \phi + \Sigma C}{\Sigma T}$

S.F. $= \frac{3.6 + 9.5}{12.1} = 1.08$

TYPICAL EXISTING CONDITION

SCALE 1" = 10'-0"

REVISION	DATE	DESCRIPTION	BY

CHARLES A. MAGUIRE & ASSOCIATES
ENGINEERS
PROVIDENCE, R. I. — BOSTON, MASS.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

DRAWN BY: S.F.S.
TRACED BY: C.R.D.
CHECKED BY: S.F.S.

FOX POINT HURRICANE BARRIER

COOLING WATER CANAL

EXISTING BULKHEAD STABILITY ANALYSES

PROVIDENCE — RHODE ISLAND

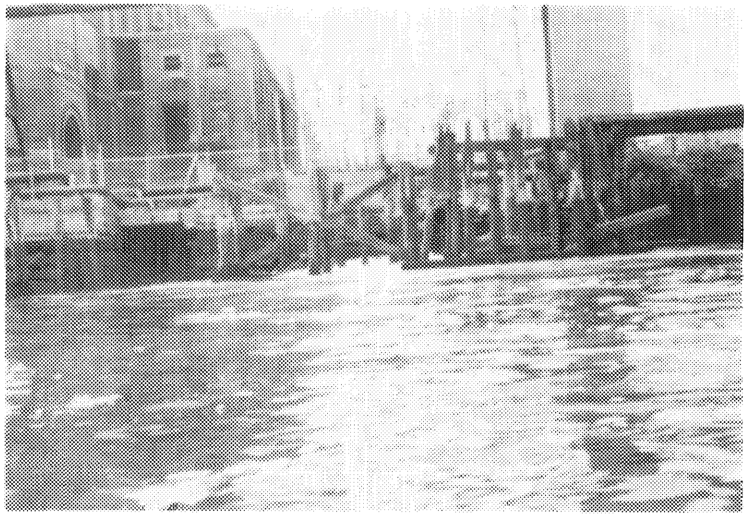
DATE: FEB. 1960

SCALE 1" = 10'-0"

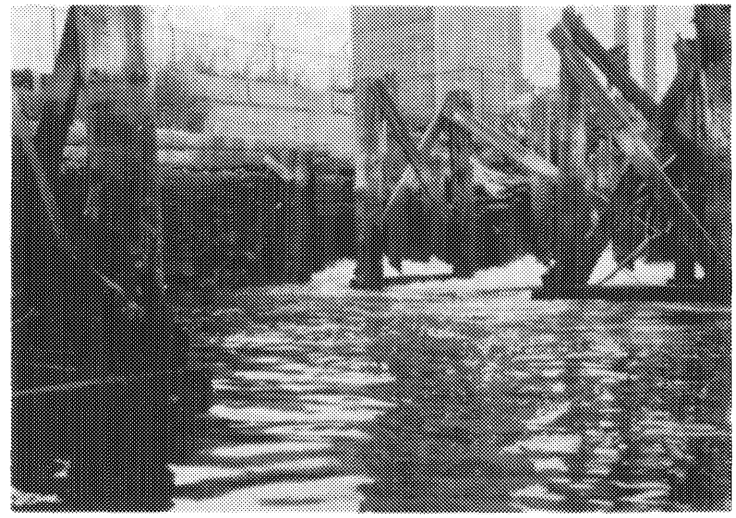
DRAWING NUMBER FP-1-1081

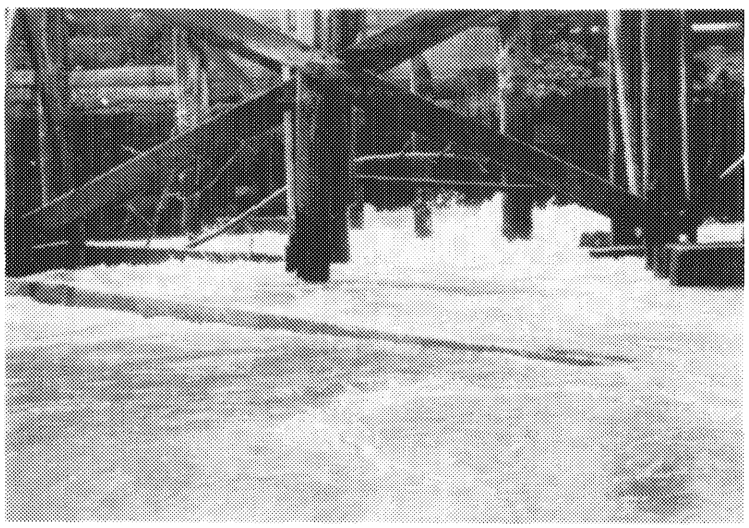
SHEET 30 OF 30

PLATE NO. II-30

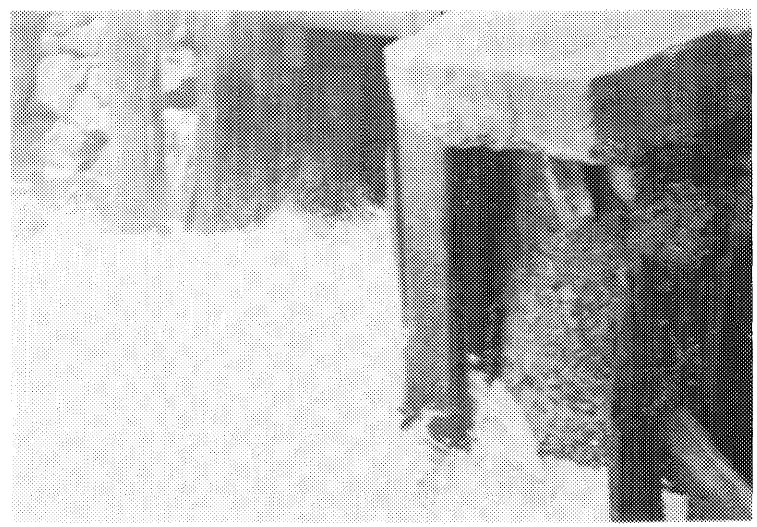


AUGUST 1959





AUGUST 1959



AUGUST 1959

EXISTING MANCHESTER STREET DISCHARGE – NORTH

PLATE NO. II-31

TEST DATA SUMMARY

FOX POINT HURRICANE BARRIER – COOLING WATER CANAL

Boring No.	Sample No.	Depth or Elev. of Sample	Laboratory Classification	Mechanical Analysis: Gravel %	Sand %	Fines %	D_{10}	Atterberg Limits: LL	PL	Specific Gravity G	Natural Water Content %	Natural Dry Density Lbs/Cu.Ft.	Compaction Data: Optimum Water %	Maximum Dry Density Lbs/Cu.Ft.	Shear Data: Initial e	Dry Density Lbs/Cu.Ft.	W_i %	W_f %	S_i %	Type Test	Specimen Size Inches	Test	σ_3 T/Sq.Ft.	σ_1 T/Sq.Ft.	c T/Sq.Ft.	φ Degrees	q_u T/Sq.Ft.	Remarks
FD-28A	J-1	0-5	ML								47.0																	
	J-2	5-7	ML								63.4																	
	J-5	16-20	ML								25.9																	
	J-6	20-25	SM								18.1																	
	J-7	25-28	ML								27.9																	
	J-8	28-30	SM								11.9																	
	J-9	30-34	SM								8.8																	
FD-28	J-5	15-20	OH								66.7																	5.2% Organic Matter
	J-6	20-24.6	OH								54.1																	
	J-16	63-65	SM	18	45	37	0.005	NP																				
	J-19	65-70	SM	21	42	37	0.005	NP																				
FD-34C	J-1	0-5	OL								163.1																	
	J-3	7-8	GP-GM	54	40	6	0.19																					
	J-5	10-15	ML	0	7	93	0.007																					
	J-6	15-20	ML								22.0																	
	J-7	20-25	ML								21.3																	
	J-8	25-30	ML	0	5	95	0.007				26.4																	
	J-9	30-35	ML								20.9																	
	J-10	35-40	ML								24.4																	
	J-11	40-45	ML	0	10	90	0.015																					
	J-12	45-50	SM	22	44	34	0.005																					
	J-14	55-60	SM	23	52	25	0.018																					
	J-15	60-63.8	SM	8	55	37	0.007																					
FD-37	J-1	0-5	OL								148.0																	
	J-2	5-9	OL								76.3																	
	J-5	10-12.7	OH								46.1																	
	J-10	25-29.6	ML								29.4																	
FD-55	UC-2	2-4	OH					120	61		196.5																	Mat'l. too oily to get G & Mech. Analysis
	UC-3	4-6	OH	0	34	66	0.001	65	36	2.64	41.5																	
											47.9																	
										2.64	40.8				1.09	78.6			99	UC	1.4φ×3						0.27	
										2.64	47.4				1.23	73.8			100	UC	1.4φ×3						0.47	
	J-4	4-6	OH								80.6				0.80	94.9			97	CD	1.4φ×3		0.54	3.42				
	UC-9	18.6-20.5	ML	0	0	100	0.004	27	20	2.74	28.5				0.72	99.2			100	CD	1.4φ×3		1.62	9.09	0.23	39.5		
											26.3				0.76	97.5			99	CD	1.4φ×3		3.24	15.69				
								26	20	2.77	27.3																	
											30.2																	
											30.8																	
											41.4																	
											32.4																	
	J-10	18.6-20.5	ML								32.7																	

TEST DATA SUMMARY

FOX POINT HURRICANE BARRIER - COOLING WATER CANAL

Boring No.	Sample No.	Depth or Elev. of Sample	Laboratory Classification	Mechanical Analyses: Gravel %	Sand %	Fines %	D_{10}	Atterberg Limits: LL	PL	Specific Gravity G	Natural Water Content %	Natural Dry Density Lbs/Cu.Ft.	Compaction Data: Optimum Water %	Maximum Dry Density Lbs/Cu.Ft.	Shear Data: Initial e	Dry Density Lbs/Cu.Ft.	W_i %	W_f %	S_i %	Type Test	Specimen Size Inches	Test	σ T/Sq.Ft.	σ_3 T/Sq.Ft.	c T/Sq.Ft.	ϕ Degrees	S_u T/Sq.Ft.	Remarks
FD-56	J-2	0-2	OH								257.7																	
	UC-3	2-4	OH							2.28	192.6																	16.6% Organic Matter
											179.6																	
											186.0																	
											186.4																	
	UC-4	4-6	OH	0	15	85	0.003	159	52	2.37	165.5																	
											183.8																	
											300.5																	
	J-5	4-6	OH								166.0																	
	UC-6	6-8	OH	22	36	42	0.007	87	43	1.99	89.0																	Plus #200 mat'l - 90% coal
											83.6																	
	J-7	6-8	OH								86.7																	
	UC-8	8-10	OH	0	8	92	0.008			2.34	93.8				2.56	41.0			86	UC	1.4 ϕ × 3						0.056	
											98.8																	
											90.9																	
											96.3																	
											86.6																	
	UC-9	10-11.7	OH								74.1																	
											35.4																	
											27.0																	
	J-10	10-11.7	OH								94.1																	
	J-11	12-14	ML								21.4																	
FD-59	J-1	5-7	SM								20.5																	
	J-4	7.3-9.3	OH								115.4																	
	UC-5	9.9-11.9	OH	0	5	95	0.001	78	38	2.57	69.6				1.73	58.8			100	UC	1.4 ϕ × 3						0.17	
											103.9																	
											79.6																	
											75.2																	
	J-6	9.9-11.9	OH								109.1																	
	UC-7	12.8-14.8	OH	0	0	100	0.001	74	35	2.67	64.5				1.73	61.0			100	UC	1.4 ϕ × 3						0.306	
											66.2																	
											65.7																	
											66.5																	
	J-8	25.6-30	SP-SM								11.9																	
	J-9	31.3-36	GP-GM								7.2																	
	J-10	38.6-43	SM								9.8																	
	J-11	43-45.5	SM								9.2																	
FD-61	UC-1	0-2	OH	0	30	70	0.003	82	40	2.99	190, 131, 83																	8.4% Organic Matter
	UC-2	2-4	OH	4	33	63	0.004	92	41	2.41	100, 154, 85																	
								63	35																			
FD-62	UC-1	0-2	OH	0	14	86	0.002	85	46	2.37	150																	Vane Shear = 0.025 TSF
											111																	

TEST DATA SUMMARY

FOX POINT HURRICANE BARRIER - COOLING WATER CANAL

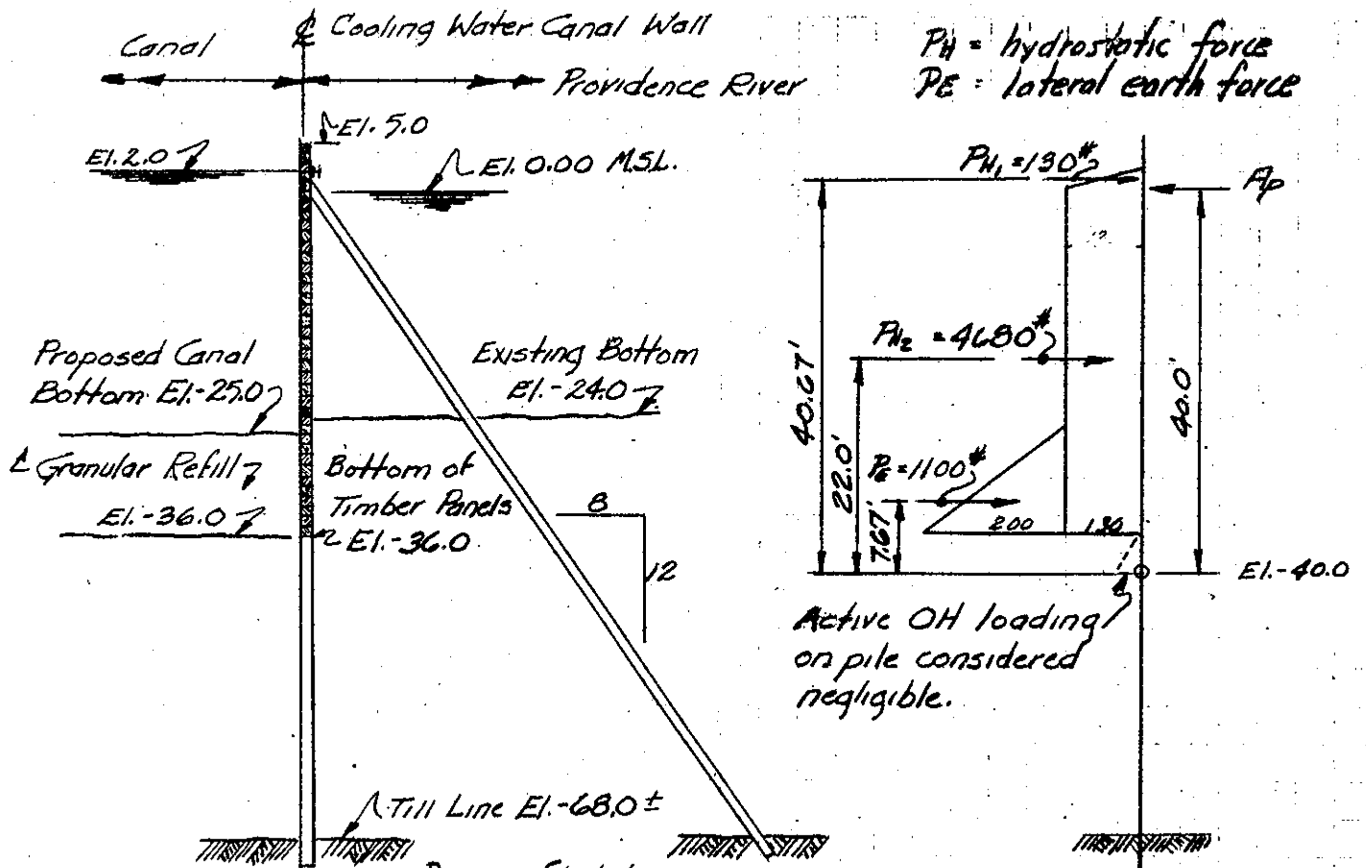
Boring No.	Sample No.	Depth or Elev. of Sample	Laboratory Classification	Mechanical Analysis: Gravel %	Sand %	Fines %	D_{10}	Atterberg Limits: LL	PL	Specific Gravity G	Natural Water Content %	Natural Dry Density Lbs/Cu.Ft.	Compaction Data: Optimum Water %	Maximum Dry Density Lbs/Cu.Ft.	Shear Data: Initial e	Dry Density Lbs/Cu.Ft.	W_i %	W_f %	S_i %	Type Test	Specimen Size Inches	Test	σ_{III} T/Sq.Ft.	σ_I T/Sq.Ft.	c T/Sq.Ft.	ϕ Degrees	q_u T/Sq.Ft.	Remarks
FD-63	UC-1	0.2-2.2	OH	5	45	50	0.007	74	41	2.42	147																	Plus #4mesh is cool
											61																	
	UC-2	2.2-4.2	SM	0	85	15	0.05																					
			OH	0	22	78	0.002																					
FD-64	UC-1	0-2	OH	0	24	76	0.004	110	48	2.28	208																	Vane Shear -0.025 TSF
											168																	13.9% Organic Matter
	UC-2	2-4	OH	0	14	86	0.002	168	69		194																	
										2.39	255																	Vane Shear = 0.025TSF
											260																	
	J-3	2-4	OH								194																	
FD-65	UC-1	0-2	OH	0	13	87	0.006	148	59	2.28	251																	
											201																	Vane Shear = 0.003TSF
											194																	
	UC-2	2-4	OH	0	4	96	0.001	69	35	2.66	58																	Vane Shear = 0.235 TSF
											64																0.29	
FD-66	UC-1	0-2	OH	0	14	86	0.002			2.23	179																	
											199																	Vane Shear = 0.010TSF
											176																	
	J-2	0-2	OH								270																	
	UC-3	2-4	OH	2	21	77	0.001	101	44	2.34	153																	
											105																	Vane Shear = 0.045 TSF
											98																	
	J-4	2-4	OH								140																	

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2

SUBJECT Cooling Water Canal Wall — SHEET NO. 1 OF

Preliminary Design — DATE 2-3 1960

COMP. A.R. — CHECK GRA — CONT. NO.



Design Sketch
Scale 1" = 80'-0"

Assumptions:

1. For design considerations, Passive Resistance of OH material against the panels & pile flange, neglected.
2. Point of contraflexure assumed @ El. -40.0 (Top of Sands and Silts.)

Loadings

Sea water $\gamma = 64.2\#/ft^3$

Granular Refill $\phi = 30°$, $c = 0$, $\gamma_d = 90\#/ft^3$, $\gamma_b = 55\#/ft^3$, $\gamma_s' = 120\#/ft^3$

$K_a = .33$, $K_p = 3.00$

OH Material

Upper Layer $\phi = 0°$, $c = 0$, $\gamma_b = 20\#/ft^3$, $\gamma_s' = 85\#/ft^3$

Lower Layer $\phi = 0°$, $c = 0$, $\gamma_b = 30\#/ft^3$, $\gamma_s' = 95\#/ft^3$

$p_w = 2.0 ft \times 64.2\#/ft^3 = 128.4\#/ft^3$ say $130\#/ft^3$

$p_e = 11.0 ft \times 55.0\#/ft^3 \times .33 = 195.65\#/ft^3$ say $200\#/ft^3$

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall SHEET NO. 2 OF
Preliminary Design DATE 2-3 1966
COMP. A.R. CHECK G.R.A. CONT. NO.

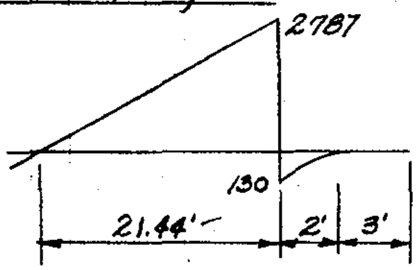
Assuming Pt. of Contraflexure @ El. -40.0

Σmom. @ El. -40.0

$(P_{H_1} = 130\#/ft^2 \times 2.0 ft \times .5 = 130\#/ft) \times 40.67 ft = 5287$ 1-#/ft ✓
$(P_{H_2} = 130\#/ft^2 \times 36.0 ft = 4680\#/ft) \times 22.0 ft = 102,960$ 1-#/ft ✓
$(P_E = 200\#/ft^2 \times 11.0 ft \times .5 = 1100\#/ft) \times 7.07 ft = 8,437$ 1-#/ft ✓

$\frac{116,684 \text{ 1-\#/ft}}{40.0 ft} = 2917\# = A_p$ ✓

Shear Diagram



Total Moment Per Foot of Wall

$130\#/ft \times 22.11 ft =$ 2869 1-# ✓
$130\#/ft \times 21.44 \times 10.72 ft =$ 29,879 1-# ✓
32,748 1-# ✓
$2917\#/ft \times 21.44 ft =$ 62,540 1-# ✓
Total = 29,792 1-# ✓

Section Modulus Req'd

assume 10'-0" spacing

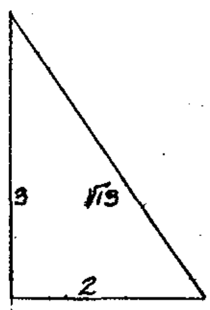
$\frac{(10.0ft)(29,792 \text{ 1-\#})(12in)}{24,000\#/in^2} = 149 in^3$ ✓

Use 14BP102 ✓
(S = 150.4)

Stress in Piling

$\frac{(29,792 \text{ 1-\#})(10.0ft)(12.0in)}{150.4 in^3} = 23,770\#/in^2 < 24,000\#/in^2$ section o.k. ✓

Batter Pile Check - Try 12BP74



$A_p = 2917\# \times 10.0ft = 29,170\#$

$29,170\# : 2 = X : 3.605$
$X = 52,500\#$ actual load $f_s = \frac{52500}{21.76} = 2420 psi$ ✓

Euler's Equation for a column with 1 end fixed and 1 end on a pivot.

$P_{max} = \frac{\pi^2 EI}{(l_{eff.})^2} = \frac{(3.141)^2(29,000,000\#/in^2)(566.5 in^4)}{(48 ft \times 12 in)^2} =$

488,000# ✓

assume effective l from El. -40.0 = 48.0 ft ✓

indicates buckling no factor

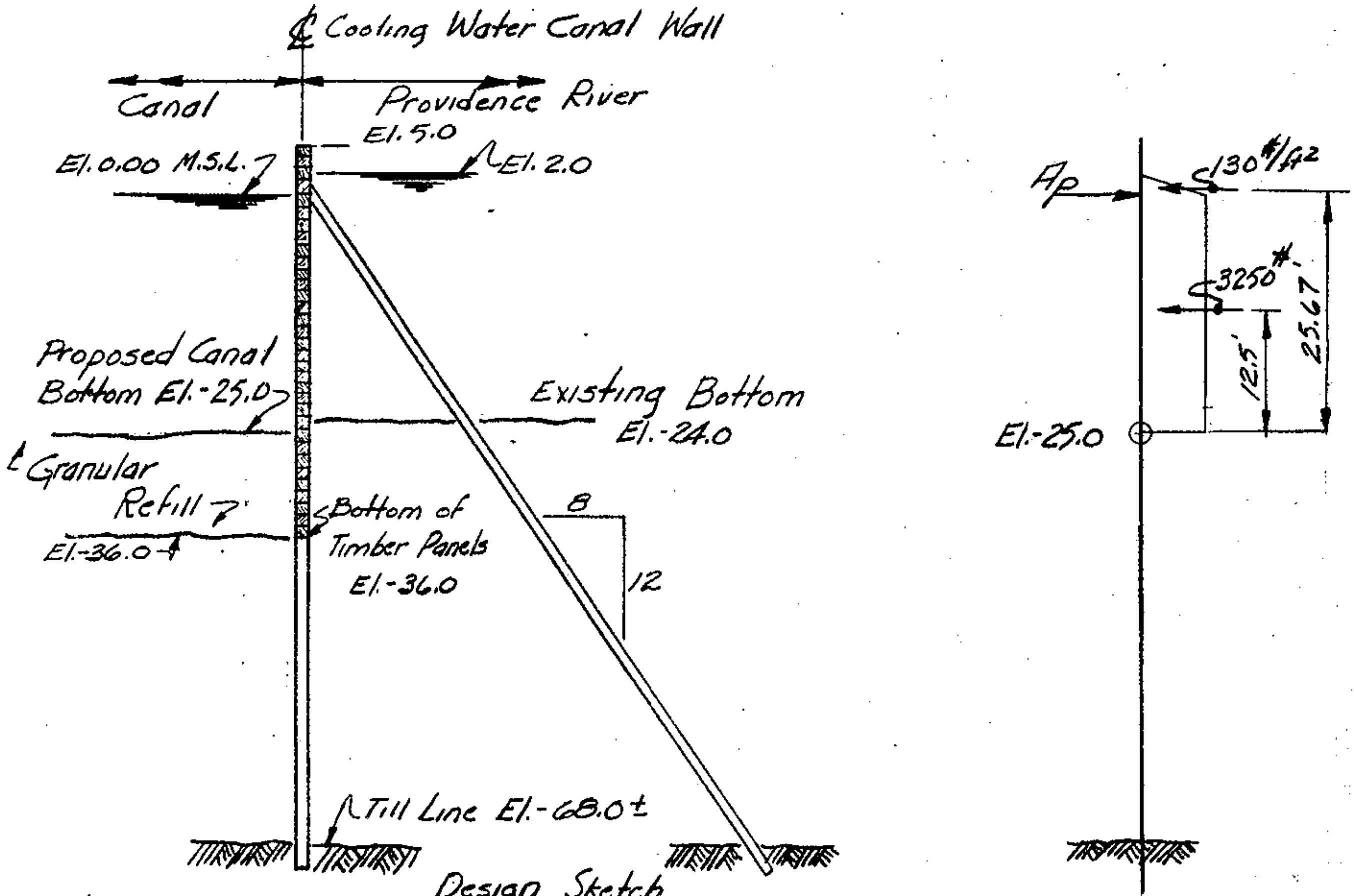
Use 12BP74 ✓

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2

SUBJECT Cooling Water Canal Wall Preliminary Design — SHEET NO. 3 OF

DATE 2-3 1966

COMP. A.R. — CHECK G.R.A. — CONT. NO.



Design Sketch
scale 1" = 20'-0"

Assumptions:

1. Since passive granular refill has a larger magnitude than the active OH material - the unsupported length of the column only was considered. Point of contraflexure @ El. -25.0.
2. Neglect small wedge of active OH acting on panels.

Loadings

$P_W = 2.0\text{ ft} \times 64.2\text{\#/ft}^3 = \text{say } 130\text{\#/ft}^2$

Assuming Pt. of Contraflexure @ El. -25.0

Σ mom. @ El. -25.0

$130\text{\#/ft}^2 \times 2.0\text{ ft} \times .5 = 130\text{\#/ft} \times 25.67\text{ ft} = 3340\#$

$130\text{\#/ft}^2 \times 25.0\text{ ft} = 3250\text{\#/ft} \times 12.5\text{ ft} = 40{,}600\#$

$\dfrac{43{,}940\#}{25.0\text{ ft}} = 1760\# = Ap$

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall SHEET NO. 4 OF
Preliminary Design DATE 2-3 1966
COMP. A.R. CHECK G.R.A. CONT. NO.

Tension on Batter Piling

$1760^{\#} \times 10.0\,ft = 17,600^{\#}$

$17,600^{\#} : 2 = x : 3.605$
$x = 31,800^{\#}$

stress $\frac{P}{A} = \frac{31,800^{\#}}{21.76\,in^2}$
1,460 psi section o.k.

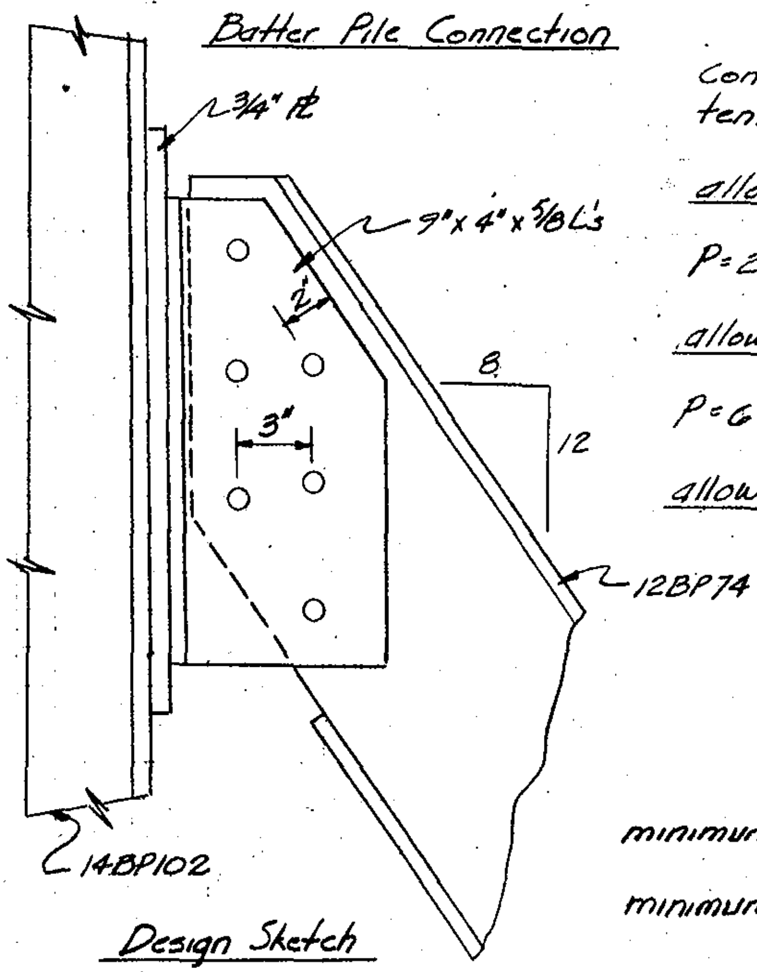
Pull Out Value

12BP74 has $4\,ft^2/L.F.$
assume $500^{\#}/ft^2$ skin friction

$$D_{needed} = \frac{31,800^{\#}}{(4\,ft^2/L.F.)(500^{\#}/ft^2)} = 15.9\,ft$$

since 53.0 ft. of batter pile is embedded in river bottom pile o.k. in pull out.

Batter Pile Connection



Design Sketch

scale 1½" = 1'-0"

Compression $52,500^{\#}$ actual
tension $31,800^{\#}$ actual

allowable load in shear

$$P = 2 \times 6 \times \frac{\pi(.875)^2}{4} \times 10,000^{\#}/in^2 = 72,000^{\#}$$

allowable load in bearing

$$P = 6 \times .875 \times .607 \times 20,000^{\#}/in^2 = 63,700^{\#}$$

allowable load in tension

$$P = [10.9\,in - 2(.875)]\,.607 \times 20,000^{\#} = 183,000^{\#}$$

Use 6 - 7/8 dia. High Strength Bolts

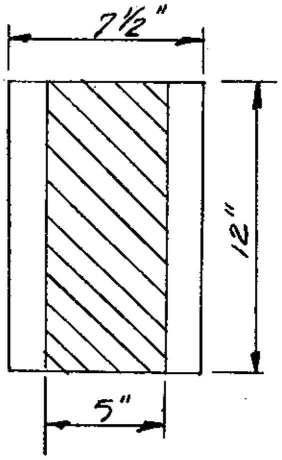
minimum pitch $3(.875) = 2.625\,in$ o.k

minimum edge distance 1¼ o.k.

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall — SHEET NO. 5 OF
Preliminary Design — DATE 2-3 196
COMP. A.R. — CHECK GRA — CONT. NO.

Timber Panels

assume 1 L.F. of paneling @ El. -36.0



For Design Considerations assume over a 30 year period that the panel under partial submergence, marine borer activity, and conditions favoring decay will have an effective d value of 5".

Max. Moment

$$\frac{(330^{\#}/ft)(10.0ft)^2}{8} = 4125^{'-\#}$$

Try 12" x 5"

$$\frac{(4125^{'-\#})(12in)}{38.81in^3} = 1275psi$$

Use 16" x 8" Timbers
Douglas Fir 1450f no.1
(creosoted)

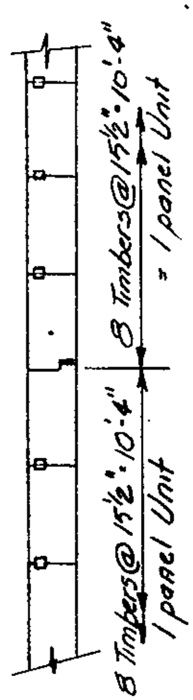
Loadings

$P_W = 130^{\#}/ft^2$

$P_{G.R.} = 200^{\#}/ft^2$

$\Sigma P = 330^{\#}/ft^2$

Panel Units



Insert 2" x 1" Oak Spline between timbers to reduce seepage

Use 3/4" ϕ to tie panels into 1 unit. 2 per unit.

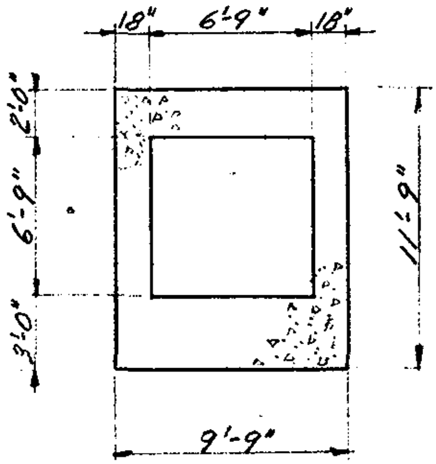
PROJECT: Fox Point Hurricane Barrier — ACC. NO. 130.2

SUBJECT: Manchester St. Sta. - North Flume Extension Structural Design — SHEET NO. 6 OF —

DATE: 2-9 1960

COMP. GRA — CHECK A.R. — CONT. NO.

Proposed Section



Buoyancy Check

Weight

Concrete: (2.0+3.0=5.0)(9.75)(150) = 7310
(1.5+1.5=3.0)(6.75)(150) = 3040

Total: 10350#

Water: (6.75)(6.75)(64.2) = 2925#

Buoyant Uplift

uplift: (9.75)(11.75)(64.2) = 7350#

Factor of Safety

full: (10350 + 2925 = 13275) ÷ 7350 = 1.8 ok

empty: 10350 ÷ 7350 = 1.4 ok

Design for Vertical Loads

Assumption: Flume extension is completly above canal level and is carrying a full complement of discharge water

Span = 53.0' center to center of bearings

Loads

concrete: 10350 #/1
water: 2925 #/1
snow: 9.75 × 40.0 = 390 #/1
13665

w = 13665 #/1

End Reaction = 13665 × 53.0 × 1/2 = 362000   R = 362000#

PROJECT Fox Point Hurricane Barrier | ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension | SHEET NO. 7 OF
Structural Design | DATE 2-9 1966
COMP. GRA | CHECK A.R. | CONT. NO.

Design Moment

$M = 1/8 \times 13665 \times 53.0^2 = 4,800,000$ ft-lbs

trial $A_s = M_s \div f_s jd$

say $f_s = 20,000$ lb/in²

$j = .88$

$d: 24 + 81 + 22 = 127$

trial $A_s = (12 \times 4,800,000) \div (20,000 \times .88 \times 127) = 25.8 = 26 \text{ in}^2$

try 19 # 9 bars lower row
10 # 9 bars upper row

29 # 9 bars, $A_s = 29.0 \text{ in}^2$

Stress Check

$\Sigma M_{cg} = 0$

$117 \times \frac{(kd)^2}{2} = 290(127 - kd)$

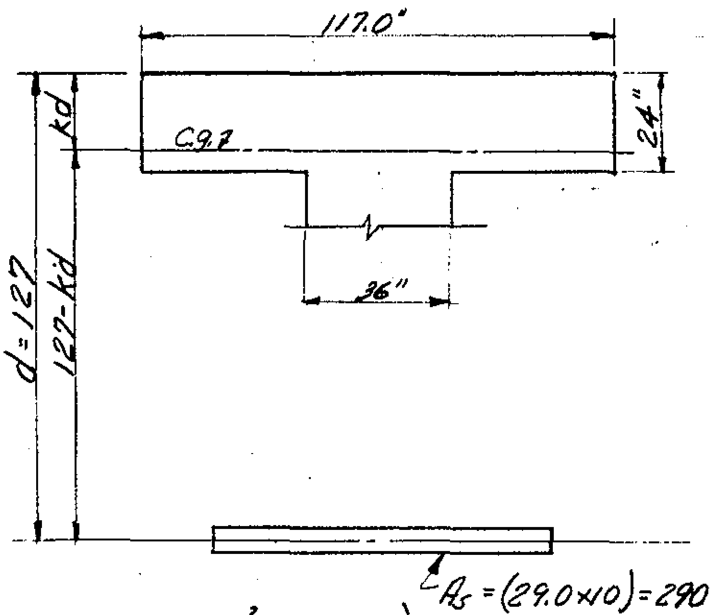
$58.5(kd)^2 = 36830 - 290kd$

$58.5(kd)^2 + 290kd - 36830 = 0$

$kd^2 + 4.96kd - 630 = 0$

$kd = 22.7$ $k = .18$

$d - kd = 104.3$ $j = .94$



$I_c = [1/12(117.0 \times 22.7^3) = 114000] + (117.0 \times 22.7 \times 11.35^2 = 342000)$

$+ (290 \times 104.3^2 = 3160000) = 3,616,000$

$I_c = 3,616,000 \text{ in}^4$

$S_c = I \div 22.7 = 159500$ $S_c = 159500 \text{ in}^3$

$S_s = I \div 104.3 = 34600$ $S_s = 34600 \text{ in}^3$

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 8 OF
Structural Design DATE 2-9 1966
COMP. GRA CHECK A.R. CONT. NO.

Stress Check

$f_c = (4,800,000 \times 12) \div 159500 = 360$ psi ok

$f_s = (4,800,000 \times 12) \div 34600 \times 10 = 16700$ psi ok

Longitudinal Shear

$v_L = \frac{V}{bjd} = \frac{362000}{36 \times .94 \times 127} = 84$ psi - ok

Bond

$u = \frac{V}{\Sigma_o jd} = \frac{362000}{103 \times .94 \times 127} = 30$ psi - ok

Use: Proposed Section

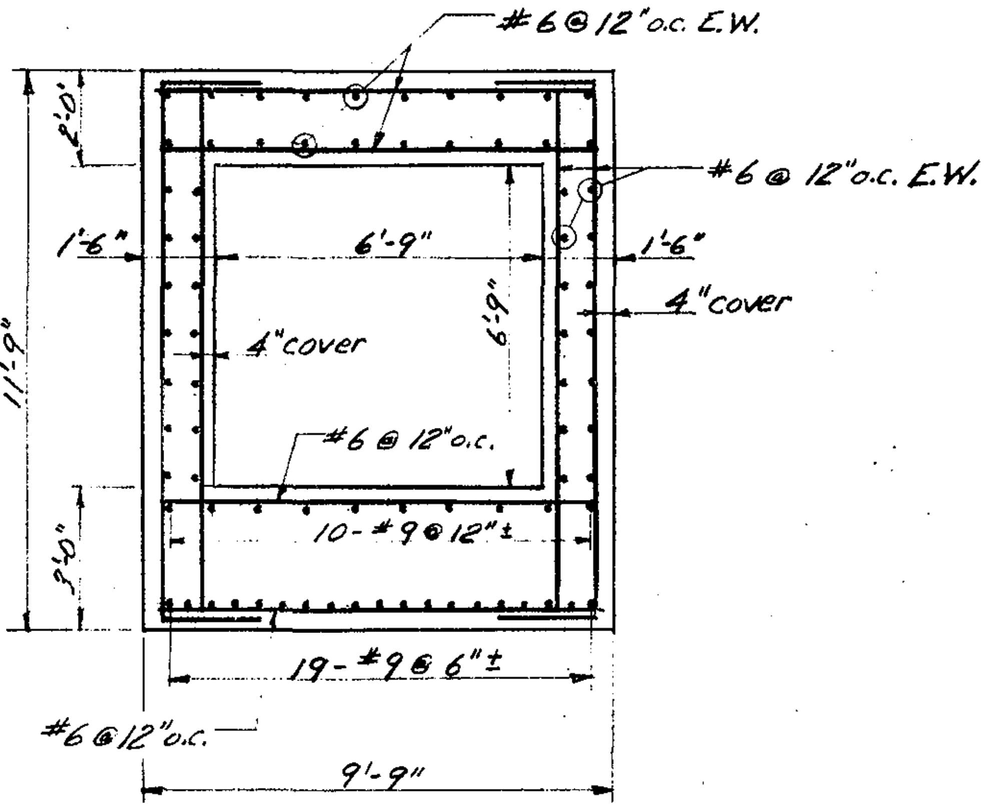
Bottom longitudinal steel - 29 #9's

All other longit. steel - #6 @ 12" o.c.

Transverse steel - #6 @ 12" o.c.

Σ_o (29 #9's) = $29 \times 3.544 = 103$ in²

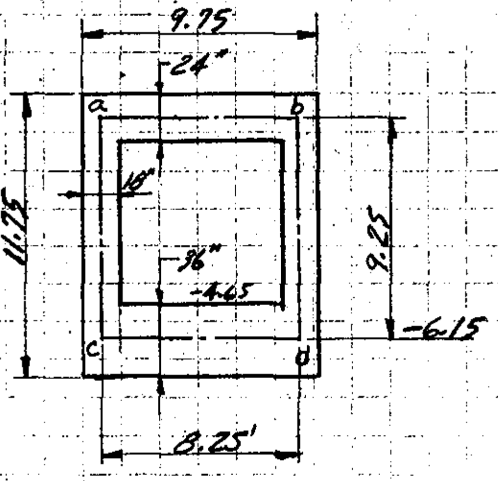
Design Sketch



PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 9 OF
Structural Design DATE 2-17 1960
COMP. GRA CHECK A.R. CONT. NO.

Check Transverse Box Section

Assumptions: water level @ elev. +6.0
neglect weight of structure & axial thrusts



$I_{ab} \propto 24^3 = 13800 = 2.4$

$I_{ac} \propto 18^3 = 5800 = 1.0$

$I_{cd} \propto 36^3 = 47000 = 8.1$

Stiffnesses

$K_{ab} \propto (2.4) \div (8.25) = .29$

$K_{ac} \propto (1.0) \div (9.25) = .11$

$K_{cd} \propto (8.1) \div (8.25) = .98$

Stiffness Factors @ Joints

Joint a

$K_{ab} = .29$ $\quad k_{ab} = .72 = .7$

$K_{ac} = .11$ $\quad k_{ac} = .28 \quad .3$

$\Sigma K_a = .40$

Joint c

$K_{ca} = .11$ $\quad k_{ca} = .10 = .1$

$K_{cd} = .98$ $\quad k_{cd} = .90 = .9$

$\Sigma K_c = 1.09$

Since 90% of any moments distributed at joint c will go to member cd, assume complete fixity at c.

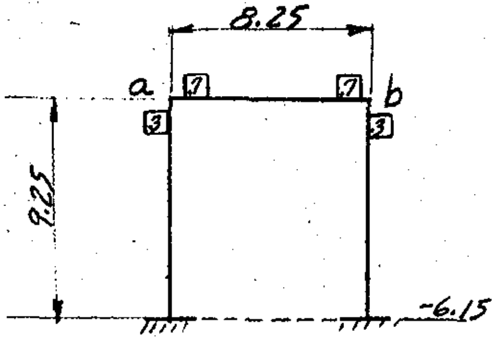
PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2

SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 10 OF

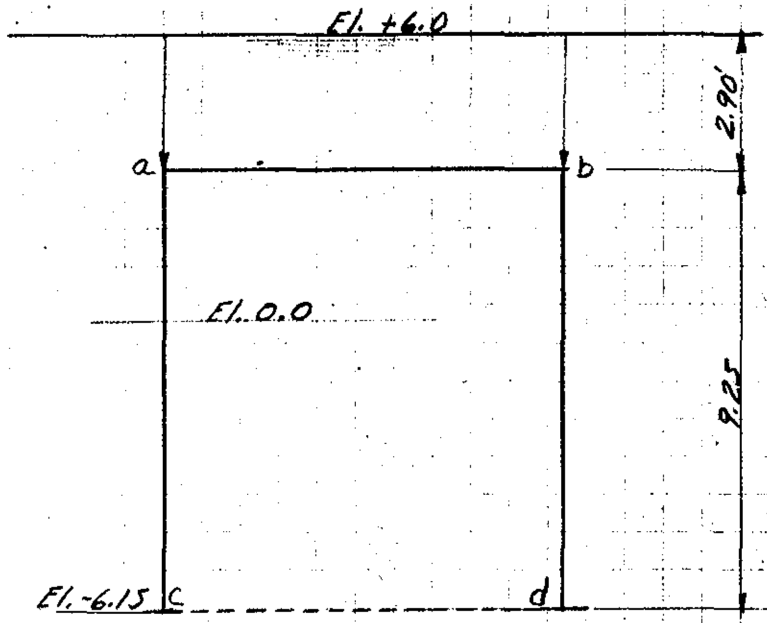
Structural Design DATE 2-17 1960

COMP. GRA CHECK A.R. CONT. NO.

Idealized Frame



Loading

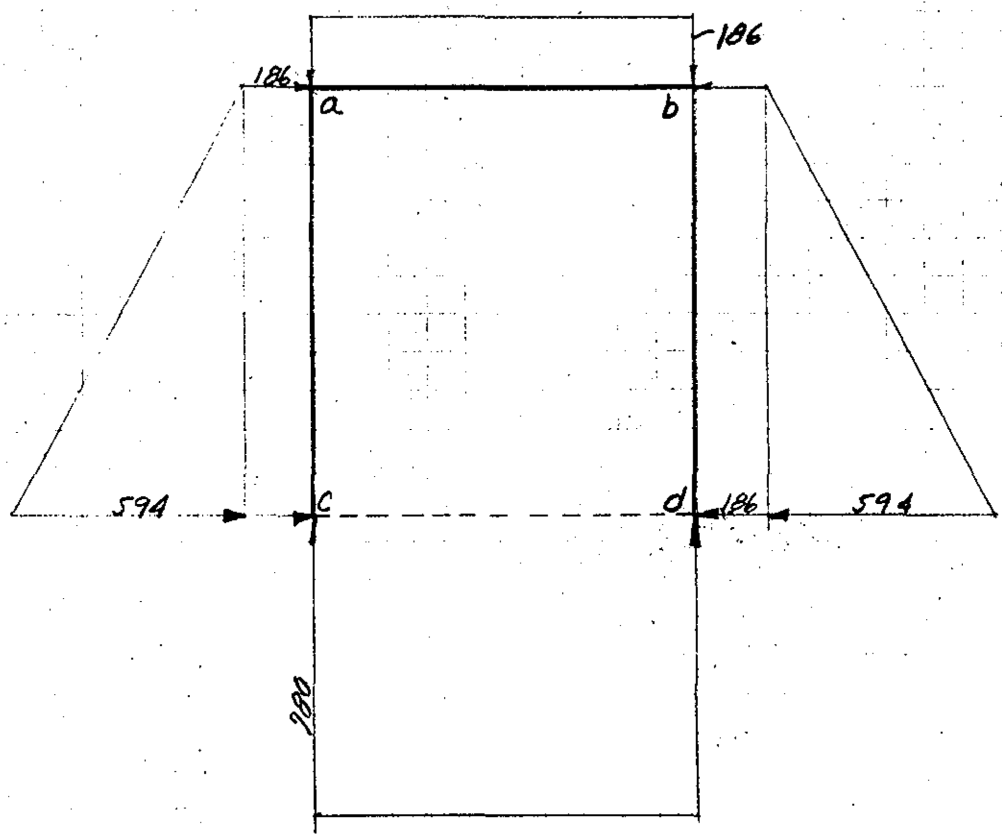


p_a = pressure @ a

$p_a = 2.90 \times 64.2 = 186$ lb/SF

$p_c = 12.15 \times 64.2 = 780$ lb/SF

$780 - 186 = 594$



PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension — SHEET NO. 11 OF
Structural Design — DATE 2-18 1960
COMP. GRA — CHECK A.R. — CONT. NO.

Fixed-End Moments

$MF_{ab} = \frac{1}{12}(186 \times 8.25)(8.25) = 1050^{'\#}$

$MF_{ac} = \left[\frac{1}{12}(186 \times 9.25)(9.25) = 1325\right] + \left[\frac{1}{15}(594 \times 9.25 \times \frac{1}{2})(9.25) = 1690\right]$

$MF_{ac} = 3015$

$MF_{ca} = [1325] + \left[\frac{1}{10}(594 \times 9.25 \times \frac{1}{2})(9.25) = 2535\right] = 3860$

$MF_{cd} = \frac{1}{12}(280 \times 8.25)(8.25) = 4400$

Distribution

a		b	
.3	.7	.7	.3
+3015	-1050	+1050	-3015
-590	-1375	+1375	+590
	+687	-687	
-207	-480	+480	+207
	+240	-240	
-72	-168	+168	+72
	+84	-84	
-25	-59	+59	+25
	+30	-30	
-9	-21	+21	+9
	+10	-10	
-3	-7	+7	+3
+2109	-2109	+2109	-2109

-906
× ½

c	d
-3860	+3860
-453	+453
-4313	+4313

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 12 OF
Structural Design DATE 2-18 1961
COMP. GRA CHECK A.R. CONT. NO.

Reinforcing Check

$A_s = \frac{M}{a \cdot d}$ where:
M is in ft-kips
d is in inches
a = 1.44, see Reinforced Concrete Handbook

Mab = -2109 ft-lbs (tension on top)
= 2.1 ft-k
D = 24"; d = 24 - 5 = 19
$A_s = 2.1 \div (1.44 \times 19) = .077 \text{ in}^2/\text{ft}$
A_s provided = #6 @ 12" = 0.44 in²/ft ok

Mac = -2109 ft-lbs
= 2.1 ft-k
D = 18, d = 18 - 5 = 13
$A_s = 2.1 \div (1.44 \times 13) = .11 \text{ in}^2/\text{ft}$
A_s provided = #6 @ 12 = 0.44 in²/ft ok

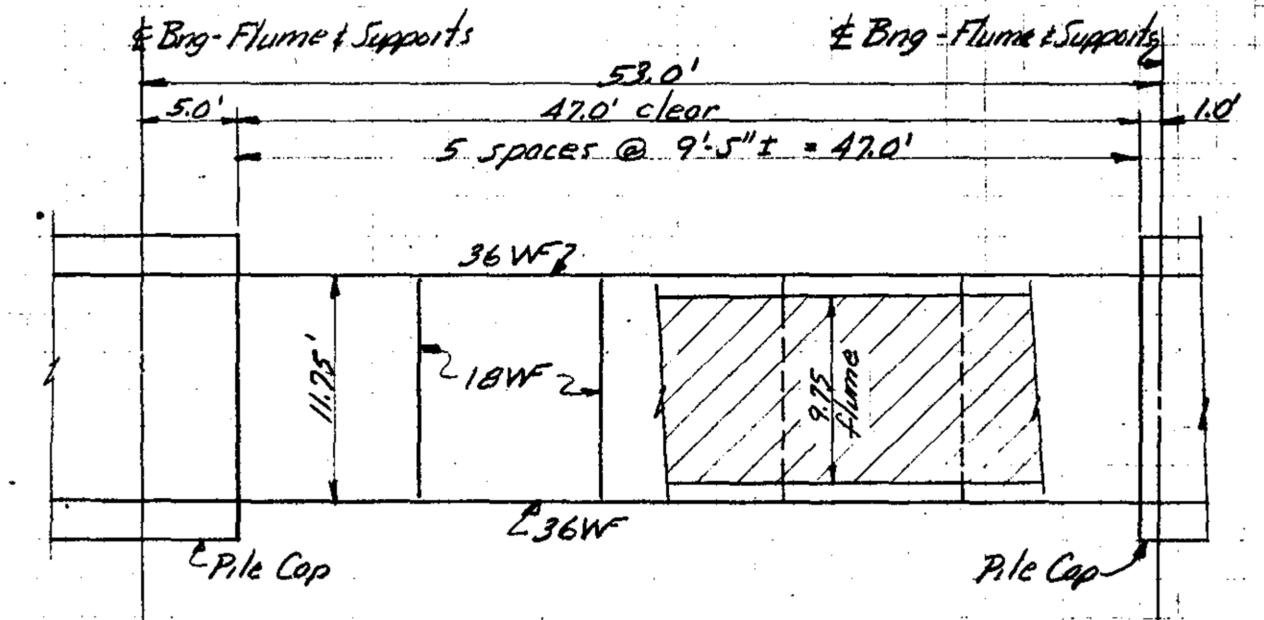
Mca = -4313 ft-lbs
= 4.3 ft-k
D = 18, d = 13
$A_s = 4.3 \div (1.44 \times 13) = .23 \text{ in}^2/\text{ft}$
A_s provided = #6 @ 12 = 0.44 in²/ft ok

Mcd = 4400 ft-lbs (fixed end assumed)
= 4.4 ft-k
D = 36 d = 36 - 5 = 31
$A_s = 4.4 \div (1.44 \times 31) = .10 \text{ in}^2/\text{ft}$
A_s provided = #6 @ 12 = 0.44 in²/ft ok

#6 @ 12" oc Transverse Reinf - ok

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 13 OF
Structural Design DATE 2-10 1966
COMP. GRA CHECK A.R. CONT. NO.

Temporary Flume Supports



FRAMING PLAN

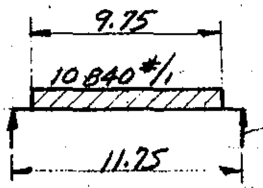
18 WF Transverse Members

assume forms = 100 lbs/SF

Loads

forms: $100 \times 9.33 = 933$ lb/ft
flume: $(10350 \times 9.33) \div 9.75 = 9910$
10843

say $w = 10840$ lbs/ft



$R = 10840 \times \frac{9.75}{2} = 53000$ lbs

$$M = \left(53000 \times \frac{11.75}{2} = 312000\right) - \left(10840 \times \frac{4.875^2}{2} = 129000\right) = 183000 \text{ ft-lbs}$$

allowable $f_s = 1.25 \times 20000 = 25000$ lbs/in²

S required $= (183000 \times 12) \div 25000 = 88 \text{ in}^3$

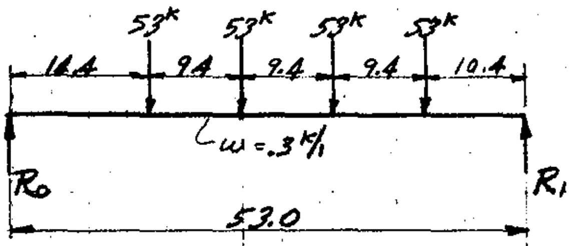
Use 18 WF 50

@ 9'-3" spacing

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension Structural Design — SHEET NO. 14 OF
DATE 2-10 1960
COMP. GRA — CHECK A.R. — CONT. NO.

Temporary Flume Supports (cont'd)

36WF Longitudinal Members



$\Sigma M @ R_1 = 0$

$53.0R_0 = 53(10.4+19.8+29.2+38.6) + (.3\times 53.0\times 26.5)$

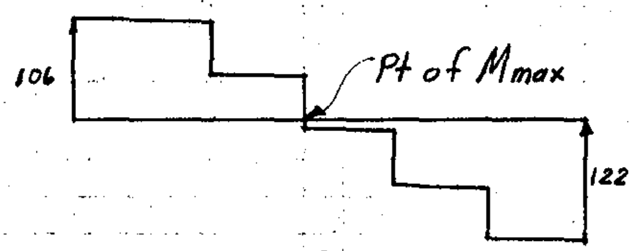
$53.0\times R_0 = (53\times 98.0 = 5200) + 430$

$53.0\times R_0 = 5630 \qquad \underline{R_0 = 106^k}$

$R_1 = (4\times 53 = 212) + (.3\times 53.0 = 16) - 106$

$R_1 = 228 - 106 = 122$

$\underline{R_1 = 122^k}$



SHEAR DIAGRAM

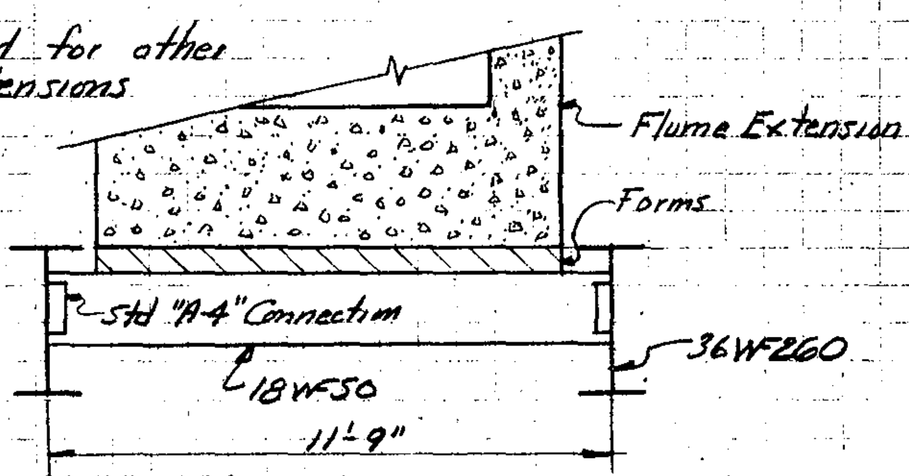
$M_{max} = (106\times 23.8 = 2525) - (53\times 9.4 = 500) - (.3\times 23.8\times 11.9 = 85)$

$M_{max} = 2525 - 585 = 1940$ ft-k

S required $= (1940\times 12)\div 25 = 930\ in^3$

Use 36WF260 *

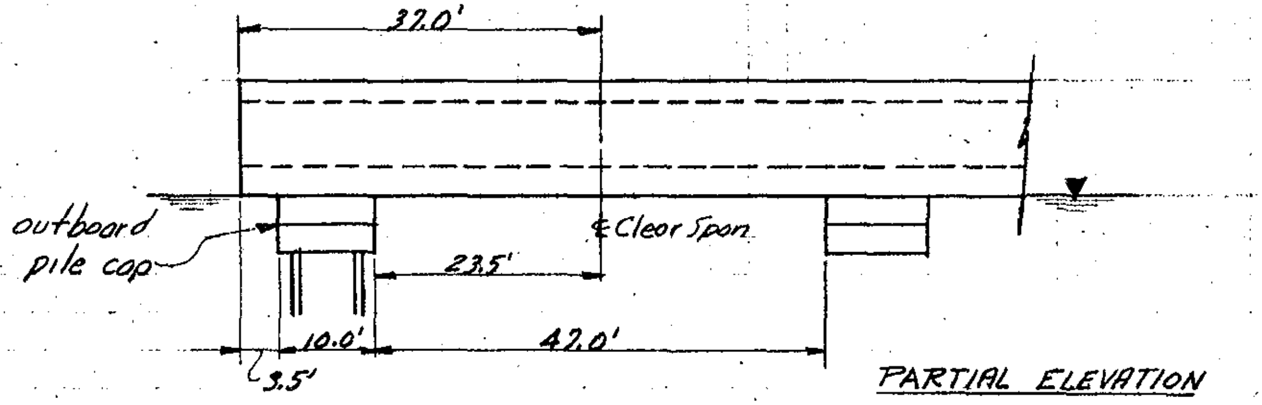
* may be re-used for other two flume extensions



Construction Framing

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension SHEET NO. 15 OF
Structural Design DATE 2-10 1960
COMP. GRA CHECK A.R. CONT. NO.

Outboard Pile Cap



Normal Operating Condition

Reaction @ Outboard Pile Cap

(assume outboard pile cap supports 37.0' of flume)

Loads

flume:	10350
water:	2925
	13275

$w = 13275$ lb/ft

Flume Reaction = 13275 × 37.0 = 491,000 lbs
Pile Cap : 10.0 × 9.75 × 3.0 (150-64 = 86) = 25,100
10.0 × 15.0 × 3.0 (86) = 38,700
554,800

Pile Type - 60 ton capacity, concrete-filled steel pipe piles

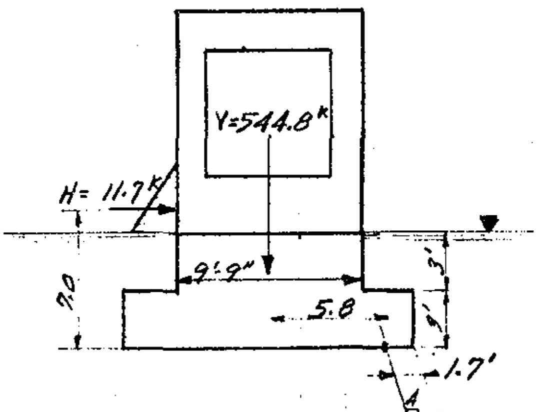
No. of piles = 554.8 ÷ 120 = 4.62 ; 5 piles indicated

PROJECT *Fox Point Hurricane Barrier* ACC. NO. *130.2*
SUBJECT *Manchester St. Sta. - North Flume Extension* SHEET NO. *16* OF
Structural Design DATE *2-10* 19
COMP. *GRA* CHECK *A.R.* CONT. NO.

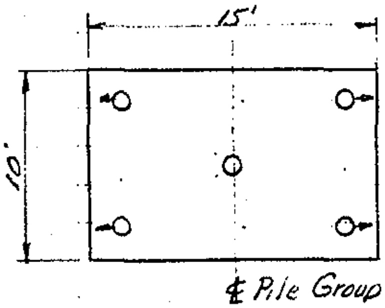
Outboard Pile Cap (continued)

Add a 3' runup wave to one side of flume thus producing a horizontal reaction on the pile cap

$H = 37.0(64.2 \times 3^2 \div 1/2 = 290) = 11\,700$ lbs
$H = 11.7^k$



SECTION



PILE PLAN

Stabilizing Moment

$M_s = 554.8 \times 5.8 = 3220^{\prime k}$

Overturning Moment

$M_o = 11.7 \times 7.0 = 82^{\prime k}$

Loc Resultant $= (3220 - 82 = 3138) \div 554.8$
$= 5.65$

$e = 5.80 - 5.65 = .15$

$M_{cg} = 554.8 \times .15 = 83^{\prime k}$

Try 5 Piles

$I_{piles} = 4 \times 5.8^2 = 135$

max $P_{vertical} = \left(\frac{554.8}{5} = 111\right) + \left(\frac{83 \times 5.8}{135} = 4\right)$

$= 115$

max $P_{axial} = \frac{12.65}{12} \times 115 = 120$ k/pile ok

Bending in Pile Cap - none

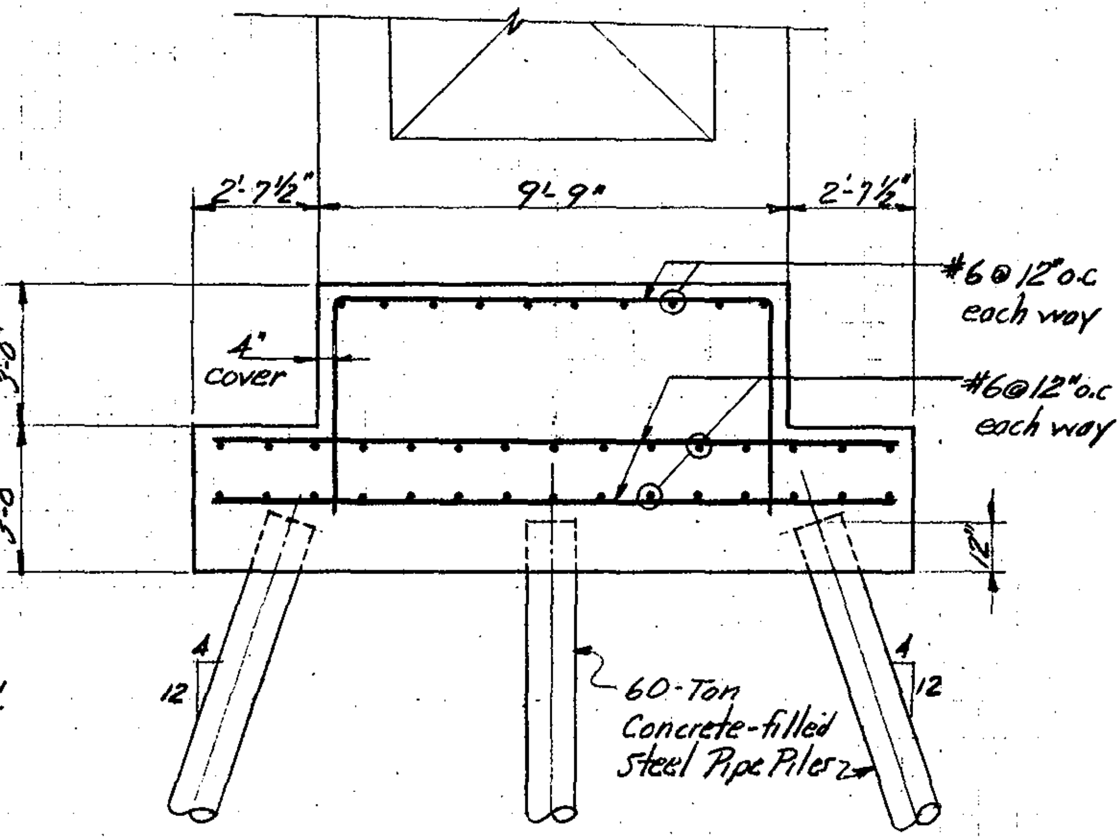
Longitudinal Shear - none produced by adopted pile arrangement

Vertical Shear: - negligible

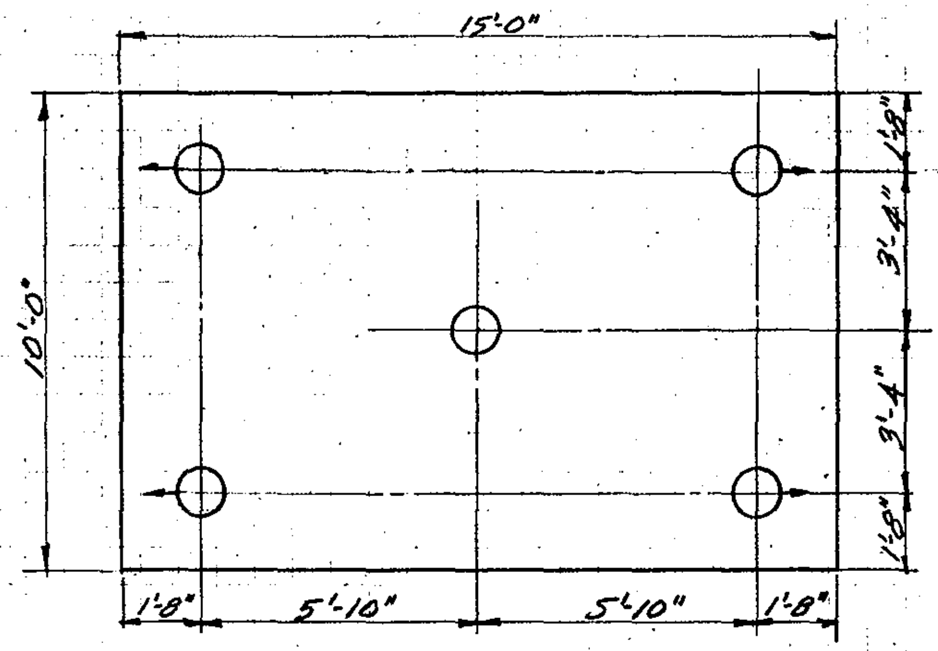
Reinforcement use nominal reinforcement - #6 @ 12"
see sketch next sheet

PROJECT Fox Point Hurricane Barrier			ACC. NO. 130.2
SUBJECT Manchester St. Sta. - North Flume Extension			SHEET NO. 17 OF
Structural Design			DATE 2-10 1966
COMP. GRH	CHECK A.R.		CONT. NO.

Pile Cap - Design Sketch



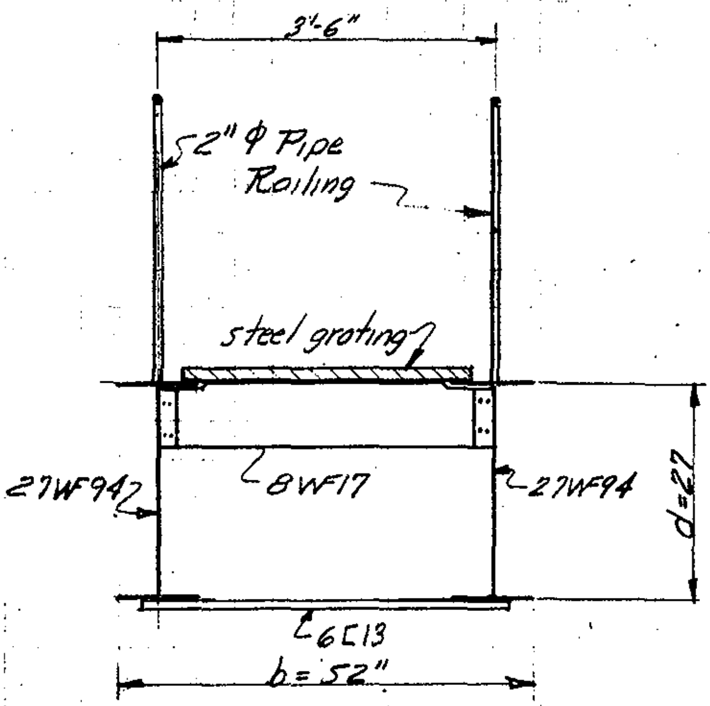
SECTION



PILE PLAN

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Access Bridge to Flap Gates — SHEET NO. 18 OF
Structural Design — DATE 2-11 1966
COMP. GRA — CHECK A.R. — CONT. NO.

Trial Section



Span = 99.0'

Fabricated beam is laterally unsupported, therefore, a reduction in working stress is indicated

$$\frac{Ld}{bt} = \frac{12 \times 99 \times 27}{52 \times 3/4} = 820 > 600$$

$$f_a = 12{,}000{,}000 \div 820 = 14600 \text{ psi}$$

Loads

Dead:	2 WF Beams	200 #/'	
	Grating 3×13	40 #/'	
	Diaphragms, etc	20	
	w_{DL}	= 260	
Live:	50#/SF × 3 ft	= 150 = w_L	
		410	w_{D+L} = 410 #/'

Bending Moment

$$M = 1/8 \times 410 \times 99.0^2 = 502500 \text{ ft-lbs}$$

Stress Check

$$f = \frac{12 \times 502500}{486} = 12400 < 14600$$

$2 \times 242.8 = 486$

27WF94's ok
Use Trial Section

Dead Load Deflection

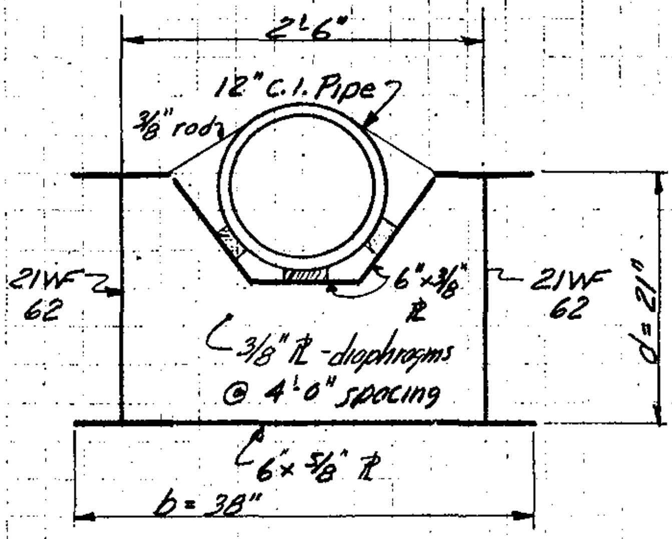
$I = 2 \times 3266.7 = 6533$

$$\Delta_{DL} = \frac{5 \times 260 \times 99.0^4 \times 1728}{384 \times 29 \times 10^6 \times 6533} = 2.95''$$

Camber Fabricated Beam 4"

PROJECT *Fox Point Hurricane Barrier* ACC. NO. *130.2*
SUBJECT *Utility Extension No. 1* SHEET NO. *19* OF
Structural Design DATE *2-11* 19*60*
COMP. *GRA* CHECK *A.R.* CONT. NO.

Trial Section



Span = 85.0'

Fabricated beam is laterally unsupported, therefore, a reduction of working stress is indicated.

$$\frac{Ld}{bt} = \frac{12 \times 85 \times 21}{38 \times 5/8} = 900 > 600$$

$$f_a = 12\,000\,000 \div 900 = 13\,300 \text{ psi}$$

Loads

12" C.I. (Class 150) Pipe:	62 #/'
Water: $\pi/4 \times 1.0^2 \times 64.2$:	50
WF's & Diaphragms: 2×75	150
	262

say w = 265 lb/ft

Bending Moment

$$M = 1/8 \times 265 \times 85.0^2 = 239\,000 \text{ ft-lbs}$$

Stress Check

$2 \times 126.4 = 253$ $\quad f = \frac{12 \times 239000}{253} = 11\,300 < 13\,300$ 21WF62's ok

Use Trial Section

Dead Load Deflection

$$w_{DL} = 265 - 50 = 215$$
$$I = 2 \times 1326.8 = 2654 \text{ in}^4$$

$$\Delta_{DL} = \frac{5 \times 215 \times 85.0^4 \times 1728}{384 \times 29 \times 10^6 \times 2654} = 3.28''$$

Camber Fabricated Beam 4"

PROJECT Fox Point Hurricane Barrier			ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall			SHEET NO. 20 OF
Engineers Estimate			DATE Feb. 19 1960
COMP. S.F.S.		CHECK G.R.A.	CONT. NO.

Steel Sheet Piling Scheme

Item	Unit	Quantity	Unit Cost	Estimated Cost
Steel Sheet Piling (MZ-27)	L.B.	2,737,800	0.14	383 292
Batter Piles (12BP74)	L.F.	13,090	8.10	106 029
Batter Pile Connections	Ea.	154	160.00	24 640
Wale System (12WF53)	L.F.	1,560	9.60	14 976
Wale Splice	Ea.	51	53.00	2 703
Protective Coatings	S.F.	156,000	0.80	124 800
Cathodic Protection (impressed current system-30 yr. cost)	L.S.			106 650
				763 090
		12% Contingencies		91 571
		Total Cost		$854661

PROJECT Fox Point Hurricane Barrier ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall SHEET NO. 21 OF
Engineer's Estimate DATE Feb. 19 1966
COMP. S.F.S. CHECK A.R. CONT. NO.

Prestressed Concrete Sheet Piling Scheme

Item	Unit	Quantity	Unit Cost	Estimated Cost
Prestressed concrete sheet piling (16" x 36" sect.)	L.F.	33,364	$18.50	$617,234
Batter Piles (14BP89)*	L.F.	13,090	9.80	128,282
Batter Pile Connection	Ea.	154	160.00	24,640
Wale System (12WF65)*	L.F.	1560	11.80	18,408
Wale Splice	Ea.	51	53.00	2,703

$791,267

12% Contingencies 94,952

Total Cost $886,219

*Cross-sectional area increased due to deduction of steel for corrosion.

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall — SHEET NO. 22 OF
Engineer's Estimate — DATE Feb. 19 1961
COMP. S.F.S. — CHECK A.R. — CONT. NO.

Prestressed Concrete Cylindrical Pipe Pile Scheme

Item	Unit	Quantity	Unit Cost	Estimated Cost
Prestressed Concrete Cylinder Piling (54" diameter)	L.F.	19,950	#35.00	#698,250
Precast Concrete Connectors	C.Y.	1,160	125.00	145,000
Reinforced Concrete Cap	C.Y.	1,850	90.00	166,500
Earth Fill (in cylinders)	C.Y.	7,820	1.00	7,820
				#1,017,570
		12% Contingencies		122,108
		Total Cost		#1,139,678

PROJECT Fox Point Hurricane Barrier — ACC. NO. 130.2
SUBJECT Cooling Water Canal Wall — SHEET NO. 23 OF
Engineers Estimate — DATE Feb. 19 19
COMP. S.F.S. — CHECK G.R.A. — CONT. NO.

Steel H-Pile Soldier Beam - Timber Panel Scheme

Item	Unit	Quantity	Unit Cost	Estimated Cost
Soldier Piles (14BP102)	L.F.	11550	11.50	132825
Batter Piles (12BP74)	L.F	12443	8.10	100790
Batter Pile Connection	Ea.	154	160.00	24640
Wale System (12WF53)	L.F.	1560	9.60	14976
Wale Splice	Ea.	51	53.00	2703
Timber Panels:				
a. Timber & Blocking	MBM	473.4	390.00	184626
b. Splines, Tie Rods, & Misc. Fittings	L.S.			10691
Protective Coatings	S.F.	72815	0.80	58252
Cathodic Protection (impressed current system - 30 yr. cost)	L.S.			49140
				578643
		12% Contingencies		69437
		Total Cost		$648,080